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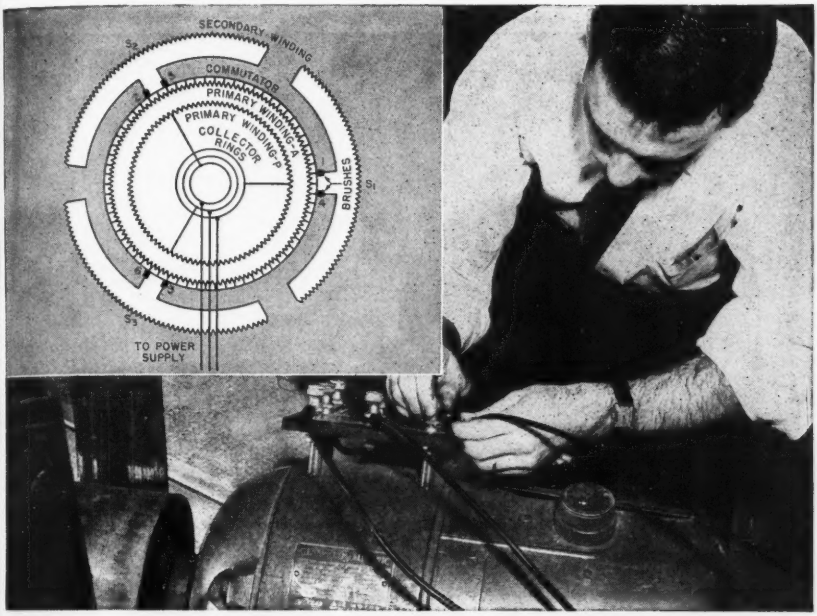

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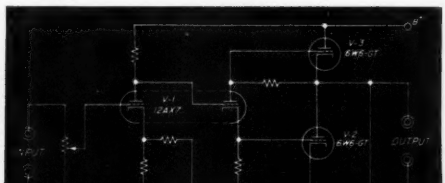

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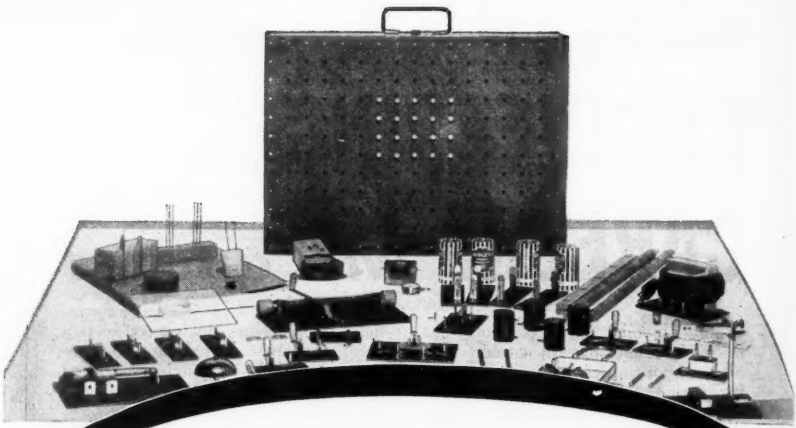

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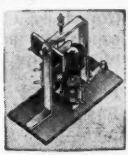

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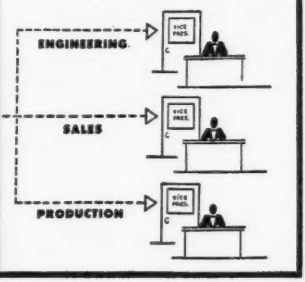

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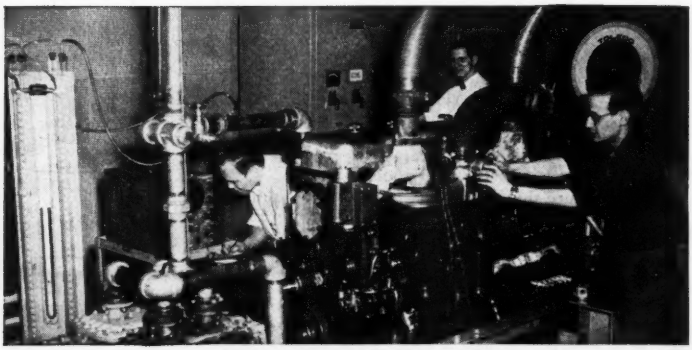

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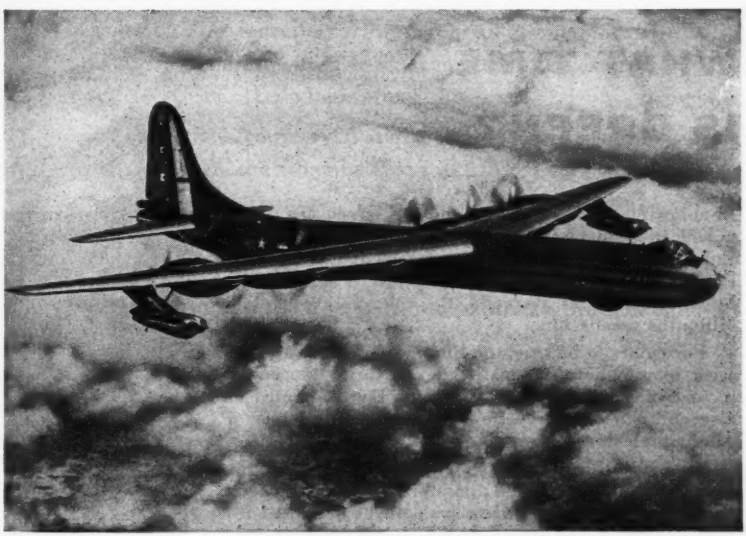

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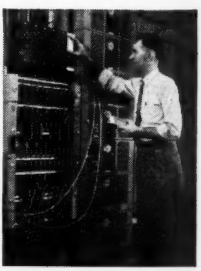

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Crafts, games, swimming, picnic lunches, science explorations, and just plain entertainment pack the day 9:30 to 5, Tuesday, Wednesday, and Thursday. The kids won't want to miss it, and Mom will be a free woman. The age groups will be 4–5; 6–7; 8–9; 10, 11, 12; and teenagers.

Register the children as far ahead as possible so they can be accommodated.

► This year the ECRC and ECAC are jointly commemorating the Fiftieth Anniversary of the founding of Engineering Experiment Stations in the U. S. by a dinner open to the Society membership. The speaker will be Dr. Lee DuBridge, President of the California Institute of Technology. The first Engineering Experiment Stations in this country were set up at the University of Illinois and Iowa State College.

► The Technical Institute Division has prepared and published a bulletin "Literature Significant to Education of the Technical Institute Type." Copies of this 60-page annotated bibliography are available at $1.00 each from Mr. Karl O. Werwath, 1025 N. Milwaukee Street, Milwaukee 1, Wisconsin.

► The Committee on Evaluation of Engineering Education held a two-day meeting at Atlanta, Georgia, February 19–20 to review some of the more controversial issues in the Preliminary Report and also to appraise the material presented in some 118 reports from Institutional Committees which have been working with the ASEE Committee. The Institutional Committee reports provided extremely helpful suggestions, many of which will be incorporated in the final draft. You will be interested to know that the Committee decided to delete the two issues which have been most controversial—bifurcation and the plan of starred accreditation for exceptionally meritorious curricula. There was almost universal disapproval of these two proposals.

The Committee recommended that the report presented in June 1954 be an interim report which would be reviewed during the next two years for subsequent modification, as well as to evaluate the progress in implementation of the report.

► The conference on Solid State Physics held at the University of Illinois, March 8–10, sponsored jointly by ASEE and the National Science Foundation, helped to clarify the essential fundamentals in modern physics as they relate to undergraduate engineering education. The

Committee came forth with recommendations of subject matter which might be included in one or two undergraduate courses and the manner in which this material can be utilized to provide a more scientific base underlying the engineering courses. It was the belief of those present that the inclusion of such material at about the Junior year could greatly strengthen the scientific foundations of the courses in engineering materials, electronics, metallurgy, strength of materials and others.

Watch for a summary of this Conference in the May issue of this Journal. Also, may we remind you of the Open Conference on this subject to be held at Carnegie Institute of Technology, June 21–25, 1954. For information write to Assistant Dean John Graham, Carnegie Institute. Dr. Frederick Seitz at the University of Illinois organized the closed conference and served as its efficient Chairman.

► There will be a similar conference, sponsored jointly by ASEE and the National Science Foundation, dealing with Nuclear Physics in Engineering Education. The Closed Conference will be held at Columbia University, April 21–23, and the Open Conference at Northwestern University, September 7–11. For information relating to the Open Conference, write to Professor Robert Young, Technological Institute, Northwestern University.

► The Mechanics Division is building its Summer School, June 11–12 at Urbana, around the theme of Graduate Study in Mechanics. The detailed program is too long to print, but the subjects sound both vital and interesting, ranging from mathematical preparation, mechanics of solids and fluids, advanced dynamics, solid state and nuclear physics, thermodynamic effects on stress analysis and vibrations, all the way to discussions of future programs. If you wish information, write to Professor Herbert R. Lissner, Wayne University, for details.

► Mechanical Engineering will hold its Summer School at Navy Pier, University of Illinois in Chicago, June 18–25. The program, aimed primarily to help the young instructor, deals with the "Teaching of Machine Design and Manufacturing Processes" and covers the entire gamut from A to Z. Professor K. E. Lofgren of Cooper Union is in charge. Here's a chance to dangle a fishing line out the classroom window and strike up a jackpot for the largest catch.

► The Committee on Engineering Economics is busy planning a two-day Summer School to be held at Urbana on June 12–13 preceding the Annual Meeting. There will be a series of seminars under the general theme "An Evaluation of Analytical Techniques of Engineering Economy," which will include "Enterprise Economics," "National Economics," "Accounting," "Statistical Techniques," and "Operations Research" as they bear on Engineering Economics. Professor A. J. Lesser of Stevens Institute, who is Chairman of the Division, can supply further information.

► From our Electrical Engineering Division comes information relating to their Summer School on "Design of Digital Control Circuits" on June 18–20 at Urbana. This will feature several distinguished Digital Computerists from the Bell Telephone Laboratories, together with demonstrations. For information, write to Dean L. V. Bewley, Lehigh University.

► The Humanistic-Social Division will hold a Summer School after the Annual Meeting, June 18–20, 1954, at Urbana. This will be a workshop to launch the new Humanistic-Social Research Project. Professor Sterling Olmsted, Rensselaer Polytechnic, will send you further information if you write.

(*Continued on page 482*)

Engineering Laboratory Courses

By JAMES N. THURSTON

Associate Professor of Electrical Engineering, California Institute of Technology

Laboratory courses are almost universally considered to be an important part of an engineering curriculum, but there is no general agreement as to what constitutes a good laboratory program. However, there do appear to be certain principles upon which laboratory instruction should be based. It is the purpose of this discussion to present one viewpoint on the subject by first stating some of these principles, and then discussing or defending them. Particular reference is made to electrical engineering in order that specific details may be considered at times.

I. The university as a whole, the engineering college or division, and the department in question should have a basic guiding philosophy of education, and this should be subscribed to, in general, by the staff, including laboratory instructors. Some engineering colleges believe in a highly specialized training, some favor a broad general coverage, while still others prefer a more thorough emphasis upon scientific principles. Of course any good school has room for a wide variation in methods and emphasis in its courses, but difficulties are sure to arise if an instructor is completely out of sympathy with the basic aims of his institution. For example, a laboratory instructor who is convinced that his students should become skilled technicians, such as might graduate from a trade school, should not attempt to force his opinion on his colleagues and his students when it is clear that the school believes in an entirely different approach. Educational philosophies change, of course, and every staff member should be free to speak and work for his ideas, but he should not be a deliberate obstructionist.

II. As a corollary to item I, it follows that laboratory courses should be planned to fit in with the general aims of a department. Furthermore, there should be a single laboratory *program,* rather than a large number of distantly related courses. As aims change, and as technological developments occur, laboratory instruction must, as a rule, change accordingly. Carefully planned changes in laboratory programs are far preferable to indiscriminate and drastic revisions. Too often there is little or no continuity in laboratory supervision, with the result that work done in the past is frequently wasted or overlooked in the confusion of a course revision. Graduate students, who are often given complete responsibility for laboratory courses, simply do not stay in the department or do not remain in charge of the courses for a long enough time to provide the necessary stability. Throughout the country there must be thousands of reams of old laboratory notes and experiment sheets that have been stored away and forgotten, only to be "superseded" by material which, upon inspection, would be found to duplicate almost exactly the earlier work.

III. Convenience of scheduling, ease of grading, and economy of operation should never be given *primary* consideration in the planning of a laboratory course.

IV. In order to be useful, a laboratory program *must* entail some preparation by the student beforehand, and *must* allow for some study and contemplation of the results obtained. Time for this outside

preparation should be clearly allocated, preferably in the catalog, and not "stolen" from other subjects.

V. Laboratory instruction should be recognized as an important part of a college program. Adequate credit should be given to those who handle laboratory courses, and senior staff members should be encouraged to participate in this type of teaching. Too often laboratory assignments are given to young and inexperienced instructors, without supervision, simply because the assignments are clearly tedious, and underrated in hours of assigned credit. The result of such a policy is obvious. Laboratories are expensive to maintain and operate. They should either be given adequate attention or eliminated entirely.

VI. Methods of laboratory instruction should be graduated to meet the student's needs as he progresses. Early courses should be arranged to offer more aid and guidance than later ones. In any case, completely detailed laboratory experiment instructions should be avoided, since their successful completion tends to show only that the student can read, that the equipment is in operating condition, and that the instructor was clever to have worked up such a good experiment.

VII. Experience in report writing is essential, and all complete laboratory programs should include attention to this principle. It may not be necessary or desirable to require formal reports in each separate laboratory course, but some report-writing experience should be incorporated in the whole program. Laboratory instructors, in marking reports, should be as careful of details related to expression, grammar, and punctuation, as they are with respect to purely technical aspects of the report.

VIII. Laboratory subjects should, if possible, be listed under separate titles and numbers in the catalog. Often it is stated that better correlation between class and laboratory is obtained if the two are listed as a part of one subject. Actually this seldom is true, since the laboratory and classroom instructors are usually not the same, the facilities are such that the same groups cannot be together in both places, and scheduling problems usually results in various mixtures of class and laboratory groups. The advantages of separate listing are considerable. Each course must stand alone and justify its existence, there is much more flexibility available for those students who have irregular schedules, and there is likely to be more attention paid to a separate laboratory course than to one which is only a part of combination. Every possibility of correlation between laboratory and class that exists with the combined method of listing is possible with the separate system.

IX. Active student participation in the laboratory should be encouraged by (a) prompt and accurate grading of laboratory performance, (b) limiting laboratory teams to the smallest possible number that can do the work (often two per team in undergraduate electrical engineering), (c) measures designed to minimize report copying and other illegal use of "files."

Other principles could be stated, but the preceding ones seem to cover the most important points. Even if there were complete agreement with the above statements, there would be many problems concerned with the detailed operation of laboratory courses. Further thought and discussion are needed on the general subject of laboratory instruction, as this area of engineering education seems to have received little attention in recent years.

Notes on: "How to Improve Our Engineering Curriculum"—Can we benefit from a comparison of the American with the European teaching methods?

By R. K. BERNARD

Professor of Engineering Mechanics, Rutgers University

The author of this paper, Dr. R. K. Bernhard, Professor of Engineering Mechanics at Rutgers University, has been educated in Europe and taught engineering subjects in this country since 1938. His experiences seem to qualify him to present a comparison and analysis of the basic teaching methods as practiced on both continents.—EDITOR.

I. *Introduction*

The great progress in the physical sciences, stimulated by developments during World War II, raises the urgent and highly controversial question at many of our Engineering Colleges: "What shall we do with our engineering curriculum in order to cope with all these new developments?"

The purpose of the following notes is, *first:* to discuss a few basic concepts of our present teaching methods, *second:* to compare them with certain European procedures, and *third:* to investigate whether we can benefit from this comparison by improving our curriculum and live up to the new situation.

This discussion is limited to technological questions only. Equally important topics on studies of the humanities are beyond the scope of these notes.

II. *General Concepts*

The fundamental questions involved are: "Do we want to educate primarily the better student, do we intend to help only the average man, or do we need programs for both?"

In other words: "Is our main purpose to raise only an elite, or to restrict everyone to the same average education, or to allow each student to make the maximum use of his abilities?"

While the European methods follow, in general, the "leitmotif" to assist a selected few, our system tends to the obviously more democratic "credo" trying to raise the educational standard of the masses. Unfortunately, the American undergraduate system tends to limit the opportunities for the more gifted students.

It certainly cannot be stated that one of the many avenues of approach is better than the other; an historical development will always follow its own path in order to fulfill definite aims.

Furthermore, whatever teaching methods are used, and often in spite of a poor teacher, the brilliant student will eventually find his way regardless.

As is often the case, most systems have their pros and cons. Hence, the next questions arise: "Can we afford to continue with our present method?" and "Is it possible to modify and adapt adequately some of the advantages of the

European procedures to minimize some of the disadvantages inherent to our system?"

American System:

Our system is based on the fact that the high schools, in general, do not prepare their students as we would prefer, in particular, as far as natural sciences are concerned. Much of the desirable course material must be presented to our engineering freshmen and sophomores which could be digested during the senior high school year.

Furthermore, we consider it essential that periodic quizzes be followed by final examinations within each semester—sometimes inadvertently degenerating into "spoon feeding."

Finally, a rigid course schedule with a predetermined number of credit hours allows only a rather small deviation from this standardized procedure. Hence, not much time is left for self studies and creative thinking.

The *advantages* of this system are:

An average student will benefit mostly from progressive quizzes and finals.

The continuous process in grading our students forms a highly satisfactory, automatic feed-back system for weak pupils, for the teachers and, if necessary, even for the parents.

All three can take preventive measures at the earliest possible moment in order to remedy any further deterioration.

In addition, the poor student can be effectively eliminated at any appropriate time by our probation methods.

The mortality of senior students is relatively low, thus presenting one of the outstanding advantages of our methods.

The *disadvantages* are:

The average student, and unfortunately the mediocre one also, will be capable to squeeze his way through struggling from one quiz to the next. If necessary, he can repeat this procedure for several semesters. Too often the tendency of an instructor may prevail to let the poor candidate pass after renewed attempts.

This rigid reining, which is so necessary for the mediocre pupil, sometimes acts as horse blinders for the better student. It might prevent him from taking a broader view, that is, exploring both sides of the beaten path.

Gifted men are rather restrained since the progress in most courses must be geared down to the average. Thus the brilliant fellow has few possibilities to proceed faster or to add more courses to his allowable credit hours.

European System:

Some European systems are based on the fact that the last two high school years are subdivided into separate branches. These branches emphasize either science courses or studies of modern or of ancient languages. In case of predominance in science studies a high school student would receive adequate training in Differential and Integral Calculus. Similar possibilities exist for physics and chemistry courses.

The extensive use of comprehensive examinations is a well established practice at many European Universities. No quizzes or intermediate finals are offered. For example, the German engineering curriculum (pre 2nd World War) comprises two comprehensive examinations only—one after the sophomore and one after the senior year. Repetitions of these two tests are severely restricted.

One typical example of a problem in such a comprehensive examination for a candidate in civil engineering, majoring in bridges might be outlined. Its solution requires several days' work and may include the following items: Theoretical and practical design of a bridge in all its details; discussion why the selected type of structure is economically justified; erection procedures and excavating methods; work-time schedules; cost estimates; financing procedure and amortization. Thus the crossing of departmental border lines between Civil-, Mechanical-, Electrical-, Architectural- and Administrative-Engineering becomes obvious.

The *advantages* of this system are:

An extended preparation in physical sciences and languages during the last two high school years relieves the standard four year engineering curriculum from the above topics. It allows the introduction of other generally more advanced courses.

The better university student will benefit mostly by proceeding with these courses at his own pace. In order to survive he has to learn at an early stage, starting as engineering freshman, to stand on his own feet. He must use his own judgment to adapt the progress according to his capacity of absorbing the subject matter as required for any comprehensive examination. That means he has to learn how to integrate many different topics over long periods of time. All of these decisions present a severe and valuable challenge to his personal integrity.

The *disadvantages* are:

A large number of high school juniors have not developed enough to indicate specific abilities.

They are not capable to select the proper branch best adapted for their future university studies.

Students with poor memory will be handicapped at the comprehensive university examinations without necessarily having a lower aptitude.

A photographic memory can act in the opposite way.

Candidates with lack of confidence seldom find the courage to enter a comprehensive examination, while men with over-confidence might fail likewise.

The almost complete freedom in study methods will lead many astray, mainly due to lack of proper guidance.

Hence, the mortality at these comprehensive tests is rather high. This presents a particularly serious disadvantage since a rejection from the selected professional career comes at a rather late date.

III. *Re-Evaluation of the Engineering Curriculum*

Numerous suggestions and experiments, independent of any European procedures, have been made at many of our universities. All of them try to prevent pitfalls inherent to both systems as analyzed above.

Two of the various suggestions adaptable to our special requirements might be discussed. They present a combination of an extended four year engineering curriculum and of an honor program. Some of these plans have been advanced and are at present under serious considerations by appropriate committees at the College of Engineering of Rutgers University.

Extended Four Year Program:

The main purpose of an extended four year curriculum is to raise the standards of the present engineering curriculum and to increase the amount of studies in fundamental sciences in order to keep up with the new technological developments.

The extended four year program is based on the assumption that the last high school year may be taught at a university. In most cases the senior high school year cannot be satisfactorily modified to fit the special requirements of a revised engineering curriculum, at least not at the present time.

Furthermore, the plan presupposes that only those high school seniors who show a definite aptitude for science studies will be eligible for this program.

Hence this suggestion has a certain resemblance to some of the above mentioned European methods. It relieves the standard four year engineering curriculum from certain basic science courses.

Finally, such a plan does not extend the duration of the present four year university studies and would facilitate a raising of our standards.

It must be kept in mind, however, that many high school seniors have not matured enough to develop special aptitudes. Consequently, this choice of a science study at such an early stage must be optional and revocable.

Honor Program:

The purpose of a university honor program may be threefold; *first:* to promote

creative thinking, *second:* to urge better students, in particular juniors and seniors, to widen their scope of studies, and *third:* to enable the brilliant man to progress faster.

Only students above a specified scholastic average can become eligible candidates and must apply on their own initiative for participation in the Honor Program.

1. *Creative thinking* can be stimulated by forming a team of qualified seniors from various departments (Civil-, Mechanical-, Electrical-Engineering, etc.). This selected group will be challenged by one comprehensive problem covering a wide range of engineering fields. The solution must require not only extensive studies in the library but also a selection of the best and, if possible, new methods. Finally, a detailed analysis of the findings is essential.

Getting accustomed to team work, to develop new angles of attack, and to inspire creative and productive research, is one of the major objectives.

2. *An increase in scope* of studies might be promoted by self studies. These self studies should include regularly required as well as elective courses. For this purpose the better student will not be forced to participate in any quizzes. He has to present himself, however, for a final examination whenever he feels that he masters the subject. Generally speaking, he will have the privilege to study when and where he sees best, according to his own discretion. The time gained by not attending classes and quizzes might be used for additional courses.

Some students, particularly the "lone wolf" type, will benefit from such a liberalized procedure.

3. The above privileges might, in exceptional cases, permit a brilliant candidate to finish his studies in *a shorter time* than the prescribed four years. This reduction in time will enable him to pursue more advanced studies than are ordinarily available to the undergraduate.

Since any rigid guidance for this selected group of students is almost completely dropped, a specially appointed faculty committee ought to continuously supervise the admission, the progress, and also the dismissal from the program of any individual candidate in case of a drop in his scholastic average.

Both programs tend to make use of some of the best qualities included in some of the European systems; first, by deliberately crossing departmental border lines, and second, by eliminating most of the continuous supervision.

To avoid misunderstandings it must be emphasized that it seems equally possible to reverse this procedure and try to improve upon the European methods. This, however, is beyond the scope of the present discussion.

IV. *Conclusions*

From a comparison of American with some European teaching concepts and an analysis of the pros and cons inherent to both systems, several clues for an improvement of our present engineering curriculum may be abstracted.

Apparently the few independent somewhat heretic suggestions, as discussed previously, have the tendency to lean towards certain European methods.

In case any suggestions are accepted in one form or another, they ought to be introduced gradually and on a small scale experimental basis. It must be kept in mind that close supervision and constant changes for improvement will be necessary.

The author realizes that the plans presented so far are only a few of the many ways in which progress can be achieved. Every institution of higher learning will require or prefer different methods.

By raising these issues he exposes himself to the dangerous crossfire intrinsic to all controversial questions; if, however, further investigations along these lines have been stimulated he would feel very gratified.

The Chemical Profession in the U.S.S.R.

By J. G. TOLPIN

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The early history of the Russian Chemical Society is similar to that of the chemical societies in other countries, notably Germany. Its journal (now called "Journal of General Chemistry") started publication in 1869. The German "Berichte" started publication in 1868. The later development of the two societies differed pronouncedly. In recent years, the rapid expansion of Russian chemical education facilities, the growth of the chemical industry in Russia, the change of the social atmosphere and of the relationship with other professional and social groups has rapidly changed the objectives of the Mendeleev Chemical Society (the present name of the chemical society in the U.S.S.R.) in many respects.

In 1913, Russia had 1000 chemists. The Russian Chemical Society (known as the Chemical Division of the Russian Physico-Chemical Society, to which both chemists and phycisists belonged), numbered 415 members in 1927. The numbers of scientists in other fields were not much different. It is difficult to draw a clear comparison between the numbers of chemists in the U.S.S.R. and in the U.S.A. at the present time, interesting as this would be. The term "chemist" is not uniformly defined on the basis of education or occupation. In 1939 the number of chemists in Russia reached 50,000 and there were facilities for training about 5000 chemists and chemical engineers a year. The number of engineers of all branches trained in 1938 was 25,200. There is reason to believe that at the present time the number of chemists and chemical engineers in Russia is close to 75,000. The American Chemical Society has now about 70,000 members. It is likely that there are up to twice that number of people in the United States employed as chemists. The number of people in this country employed as engineers and biological and physical scientists was reported in 1952 to be 600,000.

The total number of graduates from Russian universities and technical colleges during the 1946–50 period was 652,000. The number of chemists among these graduates was not stated. The total number of graduates from United States universities and technical colleges during the same period was 1,630,438.* Degrees in chemistry granted during the period 1948–50 totaled 35,217 in the United States.

In 1948, 64% of all Soviet scientists including chemists were between the ages of 30 and 50. The number of women in scientific and engineering research is large. In 1941 there were over 15% women in the various technical professions in Russia and at least 25% of all students in the technical colleges were women. In all likelihood, this percentage has not decreased after the war.

Privileges Extended

Although the great majority of the professionals, including chemists and chemical engineers, did not collaborate in the revolutionary movement in 1917, many of them later stayed on their jobs and, when the industrialization drive was started in 1928, they wholeheartedly collaborated out of sheer patriotism. This attitude

* Estimated, as figures are not available for 1946–47 graduates.

was revealed even by some Tsarist generals who served the Soviet government. In the case of scientists, many privileges were extended to them and in the course of years a series of new incentives and methods of exerting pressure upon scientists was developed in order to keep them in line politically and promote their interest in research and development work along the lines laid down by the Soviet government through its industrial planning organizations and the Academy of Sciences. All these influences are relayed through the organizations in which the chemists participate. Important among these is the Mendeleev Chemical Society.

The inducements mentioned above are not much different from those available to employees in capitalist countries; they differ only in emphasis and include public recognition, award of prizes and medals, remuneration for patentable invention disclosures, election to honorary positions and promotions.

The primary objective of the Mendeleev Chemical Society is to organize the chemical personnel for the fulfillment of that part of the over-all plans of the State which is thought to be within its sphere of activity. It arranges lectures and discussions on pertinent subjects and contests for researches on problems the solution of which is urgently needed by the national economy. These problems may include a mathematical study of a given process or application of a known reaction. The pride of Russian organic chemists, the S. V. Lebedev process for the synthesis of rubber from ethyl alcohol via butadiene, resulted from one of the first contests of this type won by Lebedev in 1927. Just as societies of engineers in various branches of industry, the Chemical Society is urging its members to file invention disclosures for which the inventor may eventually be rewarded in proportion to the savings effected by his invention. A Stalin prize involves an outright award of a considerable sum of money, between 25,000 and 200,000 rubles. Election to the Academy of Sciences contributes greatly to the prestige of a scientist. On the other hand, the Mendeleev Chemical Society collaborates with such bodies as the Department of Chemistry of the Academy of Sciences in keeping the direction of the chemical researches not only close to the needs of the national economy, as described by the plans, but also close to the dogma laid down by the philosophy of the State. A meeting on the nature of the chemical bond was organized in 1951 by the Department of Chemistry of the Academy of Sciences in order to reprimand publicly the chemists who allegedly harmed Russian chemistry by insufficient recognition of M. Butlerov's views on the structure of organic molecules and supported the resonance theory of Linus Pauling. One may think that some of the chemists who recanted at that meeting and even some of the accusers paid lip service to the interpretation of the State philosophy handed down from above at that meeting but this dictate is illustrative of the type of public condemnation and criticism to which a Russian scientist may be subjected for deviation of his views from the accepted theory as well as for insufficient adaptation of his research to the needs of the Soviet industry and Soviet theoretical science as decreed by the managers of Soviet science.

Training

The training of a Russian chemist involves a four- or five-year period of study after graduation from a secondary school —i.e., after 10 years preliminary education. A chemist or chemical engineer is clearly distinguished from an assistant engineer occupying a more subordinate position. The number of these engineering assistants, who are trained according to a well developed program of technical secondary school education, is considerably larger than that of chemists and engineers. The graduate chemist may engage in teaching, research or industrial work; the latter is more frequently done by chemical engineers. In any case, he may want to pursue graduate study for an advanced degree. There are two de-

grees which he can obtain by post-graduate work, pursued either in an institution of higher learning or in an authorized research institute; this work is carried out in many cases in absentia, except for the final year or so and examinations for which the candidate appears in person. These degrees are Candidate of Science, roughly equivalent to a master's degree, and a doctor's degree, which is officially termed doctor of the respective science, such as Doctor of Chemical Sciences. The term Doctor of Philosophy is reserved for those specializing in the field of philosophy proper. In pre-revolutionary Russia, obtaining a doctor's degree involved exceedingly much work in preparation of a dissertation. At the present time, the requirements are less rigorous and some positions, such as that of full professor, are filled as a rule only by individuals holding that degree; nevertheless, there is evidence that obtaining a doctor's degree, for instance in chemistry, is still a formidable undertaking. A chemist with such a degree will almost always sign his articles with "Doctor of Chemical Sciences" following his name.

Although the rate of training chemists in the U.S.S.R. is high and in 1942 it was stated that there were 70 institutions with facilities for chemical training, considerably fewer institutions are available for graduate training and there is a constant drive, evident from the proceedings of various bodies responsible for training of scientists, to improve the graduate research and the qualifications of the upper-grade chemist. Some leaders of research are apparently so overburdened with directing research, writing, teaching, and other duties that they neglect supervision of graduate students, or "aspirants" as they are called, for which they are occasionally publicly reprimanded. A. A. Balandin, a leader in catalytic chemistry, trained within 25 years only nine people for the doctor's degree. It is to be remembered, however, that the training for the doctorate in natural sciences, agriculture and engineering was reserved until recently for institutes of the Academy of Sciences. Only in 1952 were eight prominent technical colleges and the Moscow State University authorized to award doctor degrees and accepted a total of 100 candidates for that degree. In 1947 the total number of people with doctor degrees in U.S.S.R. was reported to be over 10,000; the number of Candidates of Science, 23,000. In 1951 there were 24,000 persons in training for the degree of Candidate of Science, and their rate of training was to be doubled by 1955, as compared to 1950. Within the same 5-year period the Academy of Sciences will train 1000 persons for the doctorate and 2500 for the degree of Candidate of Science. The Academy awarded 91 doctor degrees and 361 Candidate degrees in 1952. All these numbers are not limited to the natural sciences.

Indoctrination

All higher education, including training in chemistry, involves indoctrination in Communist theory, and no individual suspected of anti-Communist tendencies will be given a responsible position.

The entire chemical research in Russia is influenced by the National Soviet Academy of Sciences and the provincial academies of sciences. In addition to the research institutes directly managed by the Academy, there is a much larger number of research institutes serving industry either on a national or a regional basis, or else serving a definite branch of an industry. The next organizational research unit in the downward direction is a laboratory attached to a plant. Important research seldom comes from these laboratories. On the other hand, the research in the national institutes of applied chemistry and in the institutes of the Academy of Sciences is carefully planned and integrated, and the progress reports underscore the number of topics on which research has been completed and those on which the completion is still pending. The chemical research institutes within the Academy of Sciences are clearly identified through their publications and progress reports; not so the in-

stitutes working for the Soviet industries. There are at least 70 chemical research institutes in the U.S.S.R. The total number of research institutes was given before World War II as exceeding 800. At least six national research institutes serve the petroleum industry.

Recognition abroad is apparently just as important to Russian chemists today as it always has been. They constitute today a vigorously growing body of relatively young, ambitious scientists who strive to assert themselves on the science stage internationally, but also as citizens of their country deserving of high esteem, which they have been given as a body, but which is constantly threatened in the case of every individual scientist.

Russian Chemistry not well followed in the United States

Language difficulties and geographical separation are responsible for a lack of information in this country about Russian chemists. Historically speaking, one of the obstacles in the way of recognition by English-speaking scientists of certain important contributions of Russian chemistry was the influence of scientists of German descent upon Russian science. Among the scientists invited at the inception of the Russian Academy of Sciences (founded in 1725) to work in that institution, the number of Germans was large; the contributions to science made by some Rusian chemists of German extraction have been great in many cases. They reported their researches in German publications, as do many other Russian scientists. Many Russian scientists with foreign names occupy important places in Russia today and are very patriotic to their country. However, credit for their researches was in the past frequently given to Germany. Thus, F. Beilstein, Paul Walden, Wilhelm Ostwald, P. P. von Weimarn and many others either started their scientific careers as Russian citizens or considered themselves Russians throughout their lives. In the St. Petersburg Technological Institute Beilstein taught for a number of years *inorganic* chemistry, while D. I. Mendeleev—*organic* chemistry. A study of the scientific literature cited by Russian organic chemists established a decrease of the German influence at the present time: around 1946 the Russian organic chemist was quoting in research papers more Russian than German references. A similar stage was reached by the American chemist in 1919. Both resulted from the rise of American chemical research.

Influence is Great

The influence of the Soviet chemical profession upon the Soviet industries is great. In line with the importance of chemistry in the Soviet industrialization plans, the third Five-Year Plan, which was to be completed in 1942 and was interrupted by the war, was termed "the Chemical Five-Year Plan" and there is much emphasis on chemistry also in the present plans. Both the incumbent president of the Soviet Academy of Sciences and the scientific secretary of the Academy are organic chemists (A. N. Nesmeyanov and A. V. Topchiev, respectively).

In the past, many new processes introduced in Russian chemical industries consisted of adaptation of foreign processes. Now original developments resulting from utilization of the available natural resources and fruition of Russian basic research occupy the Soviet chemist. It is true that a Russian chemist, just like a chemist elsewhere, has to be mindful of economics and certain chemically interesting processes are not commercialized for this reason. Speaking about such processes and claiming credit for their development, Russian chemists are very noncommittal in many cases.

Looking at the future, the Russian chemist is confident of increasing success within his own sphere of influence, but the policies of the State and their eventual influence upon him he cannot predict.

Fundamentals and Professional Thinking

By M. L. MILLETT, JR.

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According to Webster originality is "independent and creative in thought or action: inventive." If then a student can apply creative means in the solving of some fundamental problem that is new and unfamiliar to him, he has originality. Also, the student who in a given situation, can apply his thinking progressively through each step until the solution is at hand has originality or is creative in thought. What then can the engineering division and the entire college do to help the student develop these qualities?

From experience, I would like to cite examples showing why the student must be able to grasp these new and unfamiliar situations and carry them through to a successful solution. I was in a position where I had to instruct some of the graduates of our engineering colleges. One fellow in particular enters my mind. He came to us from a school in the West and from his record he was an average or perhaps slightly above average student. He was assigned to assist in some brake tests on a particular airplane. The explanation of this type of test does not occur in the normal course work pursued in college, yet it involves some of the basic fundamentals of engineering or physics. This fellow was at a loss to know what to do. Each item of procedure and data reduction had to be thoroughly explained to him, not once, but in some cases, several times before he could grasp the significance of the problem or its solution. The situation got very strained in other instances and this fellow was very close to losing his job. As a result of his apparent lack of a good foundation, he was put on jobs where very little thinking was required other than to follow instructions.

Another engineer, from a school equivalent in standing, came to work in our group a few months later. This fellow could be easily taught and was able to grasp situations of a similar nature as those mentioned above and think them out himself with satisfactory and systematic results. This type engineer, well grounded in basic fundamentals, progresses much faster and will, as a result, receive more detailed work and have more responsibility given to him.

Industry is pleased when they receive the latter product because he reaches his productivity "break-even" point earlier and becomes an asset to the company rather than a liability. This is shown by advancements, increases in responsibility, and increases in the monetary compensation which he receives.

Concepts of Fundamentals

First of all, the engineering colleges should teach fundamentals. What are fundamentals? Again defining, "fundamentals are foundations or essentials: a principal law, or article which serves as groundwork of a system."

The following four points might help to visualize the concepts of fundamentals.

1. A knowledge of physical theory equal to the feeling and knowledge of musicians for performance of a musical instrument.
2. Ability to express conventionally such physical theory by words, diagrams, and mathematics as may be desired by the individual or as required by circumstances.

3. Ability to apply such theory in competition.
4. Ability to move among people with a minimum of friction requiring training in convention and principles of sociology and of business and a suitable personality.

Let us spend a few minutes considering each of these.

A musician who is trained properly not only knows his instrument but also knows the fundamentals or essentials of the instrument as well as the music he is playing. He can apply himself to his instrument and to the music he is presenting. The musician can also adapt himself to a piece of music that is of a slightly different tempo, rhythm, etc. An engineer should be so trained that he also knows the fundamentals or essentials of his chosen profession so that he can apply himself regardless of the situation that arises. The engineer so trained has the ground work to progress using these essentials and fundamentals.

Secondly, the engineer should have these essentials so instilled in him that he can express a fundamental or an application of a fundamental that must be used under certain circumstances. These circumstances can vary from day to day and many times during the day. One good example of these varying circumstances is in flight testing. An engineer must be able to conduct a satisfactory program to attain the data needed. At one period of the day he may be called on to conduct a certain test involving engine cooling, while later on in the day he may be required to obtain stability and control data.

Thirdly, all students once they leave college with their diplomas enter into a highly competitive field, where selling of themselves is very important to their advancement. The graduates of our colleges must be so founded that they can apply the theories, fundamentals and basic knowledge when under the pressure of competition. The engineer's foundation can be his downfall. If he is founded on formulas to use here and there, he is soon lost in the sea of competition which may completely engulf him if he gives up.

Finally, an engineer must, shall we say, "work in a laminar flow region," such that he can be among people and move among these people with the least amount of friction. To cite an example, I had to work with about five different groups of people of varying levels of intelligence, ability and environment. Management, engineering, CAA, and the shop as well as my immediate supervisors had to be dealt with and pleased in almost all instances. A person who rubs people the wrong way could start a wave of bad feeling which, of course, would end in making the job much harder and the desired goals more difficult to reach. In meetings, it is very easy to pick out the individuals who can "get along" and those who are always stirring up agitation by side remarks or sarcastic statements.

How can we as teachers instill these fundamentals into our students so they have them available when necessary? I believe that we should mention here the three objectives that we should strive to achieve. These are: 1) develop understanding, 2) learn a skill, and 3) present facts. If the student is presented fundamentals, his understanding of these essentials will deepen and be further instilled in him. With these essentials he then can broaden not only his understanding but also his skill in applying the fundamentals to new and unfamiliar situations. It should be pointed out here that the student should realize what is behind these essentials and why they are especially important to him. This, I believe, can be done by showing the students where these fundamentals were derived, how they came about and the necessity for such a basic structure of fundamentals.

General Applications

Once the fundamentals are presented, general applications should be noted, both by the instructor and by the student. Such fundamentals might be in the form

of the general force equation of aero-hydro-dynamics. The students, by having their thinking stimulated, can cite examples of applications of this general equation in finding lift, drag, thrust, torque and the various other forces on an airfoil, body or propeller. Stereotyped problems should not be presented too often because when the student starts his work in industry and finds a problem that is not exactly like that shown in class, he is at a loss to realize how to proceed in its solution if he doesn't have the groundwork of fundamentals. What are stereotyped problems? In my thinking, stereotyped problems would be those that refer to some specific formula that could be used in each case with little thought required by the student. This produces a static mind and not a dynamic one that must think to solve the problem at hand.

Work should be given to the student that causes him to think. Thought provoking problems should be presented and the student given adequate time to think them out using the tools, fundamentals and essentials at his fingertips. The thought patterns of the student will be developed to a great extent by this procedure. I do not believe that a problem such as this given one day should be answered or worked out by the instructor the next time the class meets. Rather, if the student dosen't have the problem, indicate hints which will help him to study the problem further to its ultimate solution and cause more thought on his part. Another point can be noted here in the use of our textbooks. It will develop our students' thought processes, if the instructor will ask them to explain the progression from, say, one equation to the other. If the student is stimulated by this type of procedure, he will, perhaps, want to know the "why" himself and begin to search, thereby developing himself further. I realize that it is difficult to stimulate the entire class in this manner, but if we can develop a deep interest and stress fundamentals, our students will perhaps begin to approach this end.

Students Should Not Be Spoon Fed

We should not spoon feed students! We should not present formulas and say, "this, this and this are true so all you have to do is substitute and you have the correct answer." This contradicts the previous paragraphs and the student becomes an automaton and essentially a calculating machine. Any untrained person could accomplish such an action.

Here again, let us point out our first example at the start of this paper. This fellow was no doubt of this variety since he could not apply himself because he was definitely lacking in the basic fundamentals. This also recalls a story or definition of a lecture, "The transfer of information from the instructors note book to the students notebook without passing through the mind of either." Let us put a block there so that the material of the lecture will pass through our students' minds and develop them and, if necessary, through our minds as well.

I realize that to accomplish the points set forth in this paper will cause in some cases more work on the part of the instructor, but, if the end result is a higher caliber product, that is our goal and is well worth the extra energy expended.

As a summary to this paper I would like to quote a portion of the Report of the Committee on Aims and Scope of Engineering Curricula in 1952 which contains the following specific objectives for the scientific technological stem :

1) Mastery of the fundamental scientific principles and a command of basic knowledge underlying the branch of engineering which the student is pursuing. This implies:

a) Grasp of the meaning of physical and mathematical laws, and knowledge of how they were evolved and of the limitations in their use; and

b) Knowledge of materials, machines, and structures.

2) Thorough understanding of the engineering method and elementary com-

petence in application. This requires:

a) Comprehension of the interesting elements in situations which are to be analyzed;
b) Ability to think straight in the application of fundamental principles to new problems;
c) Reasonable skill in making approximations, and in choosing the type of approach in the light for solution—in sum, a foundation for engineering judgment;
d) Resourcefulness and originality in devising means to an end.

In the News

Russian has been translated into English by an electronic "brain" for the first time. Brief statements about politics, law, mathematics, chemistry, metallurgy, communications and military affairs were submitted in Russian by linguists of the **Georgetown University Institute of Languages and Linguistics** to the famous 701 computer of the **International Business Machines Corporation.** And the giant computer, within a few seconds, turned the sentences into easily readable English.

A girl who didn't understand a word of the language of the Soviets punched out the Russian messages on IBM cards. The "brain" dashed off its English translations on an automatic printer at the breakneck speed of two and a half lines per second. "Mi pyeryedayem mislyi posryedstvom ryechyi," the girl punched. And the 701 responded: "We transmit thoughts by means of speech."

More than sixty Russian sentences were given to the "brain" altogether. All were translated smoothly in a demonstration performed jointly by Georgetown and IBM as a phase of IBM's endowed research in computation.

A handful of men had been individually engaged in research at various institutions for almost a decade to make a machine convert the meaning of words clearly from one language to another. No practical results were achieved until Georgetown a year and a half ago enlisted the aid of the most versatile electronic "brain" extant, the IBM 701.

This amazing instrument was interrupted in its 16-hour-a-day schedule of solving problems in nuclear physics, rocket trajectories, weather forecasting and other mathematical wizardry. Its attention was turned at brief intervals from these lightninglike numerical calculations to the altogether different consideration of logic in an entirely new and strange realm for giant electronic data processing machines: the study of human behavior—specifically, the human use of words. The result was an unqualified success.

Drawing Division Looks at Future Engineering Education

By DEAN JASPER J. GERARDI, *University of Detroit;*
PROFESSOR F. A. HEACOCK, *Princeton University;*
PROFESSOR JOHN T. RULE, *Massachusetts Institute of Technology;* and
PROFESSOR W. E. STREET, *Agricultural and Mechanical College of Texas,* Chairman

Drawing is the universal method of recording and communicating certain types of information in the engineering profession. Therefore, before an idea takes form or a structure or a machine is built, much informational data must be developed and represented graphically. In years past instruction in drawing placed great emphasis on technique and artistic appearance, and included some training in methods of projection in all four quadrants. Most drawings were inked and much time was spent on well executed lettering. Today drawings are quickly made and well adapted to modern production methods. Drawing courses are improved, keeping pace with the rapid advances in science, industry, and technology. Our industrial success is due in large measure to efficient planning on the drawing board. The more complex the production problem, the more urgent is the need for effective drawings to show the workman exactly what is required. As future progress will depend more than ever upon better working drawings, the drawing teacher today accepts the responsibility of giving engineering students the right kind of drawing instruction, so that the engineer of tomorrow will have the best working knowledge and drafting ability to plan future developments.

Analytical Tool

Nor is it out of place here to state that drawing in all its forms is a foremost instrument in sharpening and deepening the powers of perception which features expanded treatment of the theory of drawing as an analytical tool. Strong emphasis on development of the student's geometrical and spatial ability, to equal his training in equational representation of physical bodies is needed, so that he can interpret shape and position descriptions to those who must construct them. "For working out the shape of objects, visualizing natural phenomena or setting up a basis for calculations, graphics is simple and self-checking. For these purposes, it has no competition and none appears in prospect."—A. F. Puchstein, Consulting Engineer, The Jeffrey Manufacturing Company, Columbus, Ohio.

It is true that many engineers today in responsible positions have draftsmen to make their working drawings from sketches. However, an engineer cannot supervise draftsmen until he becomes proficient in reading and making drawings. Just as the engineer is responsible for the proper functioning of machines and machine elements, he is equally responsible for drawings showing their design, for the selection of correct dimensions, for the proper choice of materials, and many other things which a draftsman has insufficient background training to determine. He must, therefore, acquire the ability to solve new problems in unusual situations, to think creatively, to continue to learn, to remain mentally vigorous, and exercise sound judgment in finding the best answer without loss of

valuable drafting time. In modern industry drawings are considered legal documents, or the basis of contracts, and they must not be misinterpreted.

Modern Reproduction Methods

A large part of engineering costs on any project are involved in making and reproducing drawings. Modern reproduction methods are now being reflected in drafting room procedures. Ink work has been replaced almost entirely by pencil drawings. Freehand sketching is being increasingly emphasized. Stress is placed on the development of an engineering vocabulary. Construction of charts and diagrams and the principles of limit dimensioning have been introduced. Since dimensioning is associated with shop processes and time for shop courses has been curtailed, it is necessary to emphasize what a machine can do and what its limitations are in order to give proper drawing specifications. In descriptive geometry the draftsman's method of analyzing and solving problems by the auxiliary plane method has resulted in students acquiring greater confidence and competence in the use of this science.

Graphics includes in its field all the fundamentals of graphical representation, and of geometrical and graphical analysis. Conventionally, it is covered in most colleges by courses in engineering drawing and descriptive geometry. These courses generally cover graphical processes of solving physical problems, fundamentals of form and design, as well as exact delineation of space objects for recording ideas. Engineering drawing is a subject of high utilitarian value. It is a technique in commercial demand and work on the drawing board is frequently the doorway to promotion. Moreover, for more than 50 per cent of the entering students who do not complete their work in engineering, it is a professional course that offers an opportunity to enter the field of technical employment.

Engineering educators recognize spatial visualizing ability as one of the prime requisites of a good engineer. Recent research by R. R. Worsencroft of the University of Wisconsin and Mary Blade of the Cooper Union indicates that present courses in engineering drawing and descriptive geometry develop this trait in engineering students to a very significant degree over other students, and that following these courses, further development is comparatively slight. This confirms the intellectual value of training in drawing to conceive and create solutions to highly theoretical problems. Drawing introduces the obligation of conforming to standards basically necessary to all engineering practice. It trains to notice subtle differences in quality. It promotes an understanding of form and design, of the feel for various materials and their possibilities. It provides fundamental training for developing creative ability and sound engineering judgment.

Industrial Problems

Careful consideration should be given to the graphical solution of industrial problems, and sufficient time provided for adequate drawing courses in the various engineering curricula. Graphical computation courses including such topics as empirical equations from laboratory data, graphical differentiation and integration, and nomography offer a fertile field for applying graphical methods in fundamental courses such as mathematics, physics, and mechanics. Further, there is a need of drawing courses to bridge the gap of one or more years from drawing to design to provide essential information and give a better carry-over and continuity. Engineering graphics has broader educational functions than developing ability to represent objects by orthographic drawings and to solve space problems by descriptive geometry methods. For graphics is a comprehensive term, including not only engineering drawing and descriptive geometry, but also the advanced courses of kinematics and graphic

statics and other similar courses in the various technological curricula.

It is recommended that drawing teachers be given greater opportunity to participate in or supervise programs which rely on graphics for solution in engineering and scientific research or development. The value of such research is demonstrated by recent projects applying drawing and descriptive geometry in the treatment of cancer by H. W. Vreeland at Columbia University and in the design of artificial limbs by A. S. Levens at the University of California.

In the News

A fund of $238,500 for grants to universities and colleges to advance the teaching of science has been announced by the **Du Pont Company.** This distinctly new part of the company's program of aid to education is the result of an experimental plan announced last year.

The company has now made advancement of teaching the largest single part of its aid-to-education program, which for many years has also provided grants for fundamental research and postgraduate fellowships. Under the whole program it has authorized a total of more than $700,000 for the 1954–1955 academic year as compared with $600,000 for the present year. In the longer standing plans in the program, the company is granting $230,000 for fundamental research and $222,000 for postgraduate fellowships in science and engineering.

The Sectional Meeting of the **World Power Conference** will take place in Rio de Janeiro, July 25 to August 10. The U. S. National Committee for the World Power Conference is working with the Department of State in organizing the U. S. delegation.

The **Interamerican Association of Sanitary Engineers** has selected Sao Paulo for their meeting. It will take place July 25 to 31. The U. S. delegation is in the process of being formed.

The Third Convention of the Pan-American Federation of Engineering Societies (UPADI) will also meet in Sao Paulo, August 2 to 12. This meeting will attract engineers of all societies from Latin America, Canada and the United States. Engineers Joint Council is currently selecting the U. S. delegates and alternates.

Teaching Tips

The Mechanical Engineering Department at Michigan State College endeavors to "Integrate the work of several courses, and to make the work in these courses meaningful and practical by designing and manufacturing small air compressors on a production basis." The project was initiated by Dean Miller while he was head of the Mechanical Engineering Department as a cooperative project of the design course, pattern shop, foundry, machine shop, and industrial engineering class. It was intended that the students should become intimately acquainted with production tools, their operation and limitations, although it was realized that great skill in these fields could not be achieved.

The compressor was designed by the students in the advanced design classes during the Spring term of 1947. The following Fall the pattern shop and the foundry cooperated in producing first metal patterns for the cast iron parts, and later the iron castings for the compressor. A number of jigs and fixtures had to be built for the machining of the various parts, including a jig for welding the connecting rods which are made of pieces of standard water pipe. All the parts are produced in this department with the exception of the piston rings and bearings which are purchased. The cast iron parts include the flywheel, cylinder, and an alloy iron crank shaft. The piston is an aluminum alloy casting made in a permanent mold. The valves are made of thin stainless steel, and the pressure relief valve of brass.

The machining operations are conducted in the machine shop on a production basis with each part having its own group of tools, doing predetermined operations on it. Sophomore students act as the machine tool operators, juniors as foremen and set-up men, and seniors act in time study, motion study, and other industrial engineering positions. Students who have helped in the production of the air compressors are allowed to buy one each if they wish at the cost of the materials.

Future Trends in Technical Institute Education*

By DR. HAROLD P. RODES

President, Ohio Mechanics Institute

Whenever a person becomes sufficiently foolhardy to predict future developments in any area of human activity, it is apparent that his forecast must be an extrapolation of his past experiences. In this case, the author's work experience has included Industry as well as Liberal Arts, Engineering, and Technical Institute education. The predictions which follow are, therefore, based upon varying amounts and types of experience in these fields:

1. It is anticipated that student enrollment in college curricula of technical institute type will increase. In addition to the obvious reasons, such as larger high school graduating classes and a greater percentage of high school graduates continuing with further education, it is anticipated that many returning service men will find a two-year collegiate program attractive because it will enable them to find full-time technical employment and to establish a normal family life as quickly as possible. More important, however, from the standpoint of increasing technical institute enrollment is the expanding need of industry for training of technical institute type. This involves the addition of curricula in Chemistry, Electronics (particularly Television), Technical Illustration, Industrial Supervision, and Construction in technical institutes which are not already offering programs in these fields.

Transfer Policies

2. The Iron Curtain which has existed between some professional engineering schools and some technical institutes will be gradually removed, so as to facilitate appropriate enrollment and transfer in both directions. You are well aware of the fact that the American Society for Engineering Education and the Engineers Council for Professional Development have taken the lead in developing a close working relationship between the different types of institutions of higher learning which are offering education related to engineering. We are entering a period when these basic policies of transfer which have been agreed upon among the higher echelon of education should be carried out at the level of the person who is most concerned about it, namely the transfer student himself.

By way of illustration, we have been extremely fortunate in Cincinnati to have developed a pattern for such a transfer relationship between the College of Engineering at the University of Cincinnati and the Ohio Mechanics Institute. Although the objectives and, therefore, the content of a technical institute curriculum differ from those of a four- or five-year engineering curriculum, there are certain similarities which should be recognized in a realistic transfer arrangement. On the basis of a conference between department heads of the University and of O.M.I., it was determined that certain courses in chemistry, mechanics, mathematics, engineering drawing, and English were sufficiently similar to justify transfer in either direction. It is now possible for qualified graduates of the two-year technical institute curricula at O.M.I. to receive approximately one year of transfer credit at several four and five-year engi-

* Presented at ASEE Annual Meeting, University of Florida, June 23, 1953.

neering schools. It is likewise possible for an engineering student completing two years of study in a four or five-year engineering school to receive approximately one year of transfer credit at the Ohio Mechanics Institute. It should be emphasized that transfer is a minor function of a technical institute and that we are discussing only a very small percentage of those young men who complete a two-year technical institute program aimed at immediate employment in industry. Nevertheless, we are just as proud of the fact that one of our graduates is on the "Dean's List" at the University of Cincinnati as we are proud of the fact that a boy who completed two years of electrical engineering at Purdue is on the "Honor Roll" in the second year of our two-year Electrical Engineering Technology curriculum. Although the number of transfer students will not and should not increase markedly, I believe that many more professional engineering schools and technical institutes should make it possible for such transfer to take place without either penalizing the student to the extent of compelling him to repeat subject matter unnecessarily, nor on the other hand expecting him to handle the work of the third year in engineering when his two years of technical institute training has not aimed in that direction. In general, the pattern will probably develop into one of approximately one year of transfer credit for two years of either technical institute or professional engineering study.

Greater Recognition

3. We can definitely look forward to greater recognition of the place and importance of technical institute education by Industry from the foreman to the chief engineer, by Education from the elementary school teacher to the university president, and by Parents from Mom to Pop.

The current technical manpower shortage has stimulated Industry to analyze the actual requirements for many technical positions. A number of companies found that they were employing professional engineering graduates in positions for which technical institute training would be more appropriate and, therefore, more satisfying. Several companies have inaugurated special orientation programs for new employees who have been educated in two-year technical college curricula. I believe that this trend will continue to the advantage of both American industry and the engineering profession.

Many counselors and educators, confronted with statistics which indicate that almost half of our high school graduates can profit from some further training at the college level, are beginning to look more and more to those institutions of higher learning which offer a two-year program in preparation for responsible employment in business and industry. As the high school graduating classes become larger and larger, this trend will undoubtedly accelerate.

Mother and Father will always want Junior to go as far in the World as he possibly can. The social prestige of a college education cannot be denied in this day and age. However, as the two-year college graduate with his Associate's Degree finds his rightful place in American industry, Junior will have both the standing and the income which will make Mom and Pop proud of him.

4. The very nature of a technical institute curriculum requires that it be constantly in close accord with the practices of the particular industry which it is serving. One of the best means of accomplishing this is through the cooperative plan of education whereby students have an opportunity to relate the instruction which they are receiving in the classroom and laboratory to actual working conditions on a cooperative job in industry. Therefore, despite the administrative headaches occasionally involved in a cooperative education program, I believe that both the "co-op" technical institutes and the cooperating companies have found such a plan sufficiently satisfying to advocate its adoption by other colleges in other communities. This cannot be accomplished overnight by indus-

trialists and faculty members who are unacquainted with the "co-op plan," but I feel confident that this system will receive wider adoption throughout the nation.

5. The technical institutes are not entirely unaware of the emphasis which is being placed upon general education in contrast to specialized education. If it is difficult to find room for additional general education in a four or five-year engineering curriculum, it is even more difficult to find room in a streamlined two-year curriculum. I predict therefore that, with the exception of certain courses in English and Psychology, the technical institute curriculum will achieve most of the objectives of general education through the teaching techniques employed in its technical courses as well as through good counseling and extra-curricular activities.

Employment Problems

6. The current shortage of technically trained manpower has created certain employment problems in education just as it has in industry. This is particularly true of the field of technical institute education which is necessarily dependent upon a corps of instructors who are not only competent and enthusiastic teachers but who also possess considerable industrial experience. It is extremely difficult in these times for a technical institute to attract to its faculty an outstanding industrial man who is in his thirties, forties or fifties and near or at his peak from the standpoint of income. Therefore, I believe that for the next few years our technical institutes will draw their faculty members from three different groups in order to maintain the high quality of instructional competence and industrial experience which must be represented on a technical institute staff. Although outstanding industrial men in their thirties, forties and fifties may not be available on a full-time basis, those who are genuinely interested in teaching but cannot afford the financial sacrifice may be employed on a part-time basis. Secondly, there are a number of good engineers and prospective teachers reaching age sixty-five who can now afford to teach because in most cases their children are self-supporting and they have only themselves and their wives to support. Our Institution recently added a truly "master" teacher from this category.

In order to balance the maturity of these two categories, there are still some young men in their twenties, fresh out of college with little industrial experience, who have a burning desire to teach and can, therefore, provide considerable assistance in the laboratories and gain some teaching experience in the basic sciences and mathematics.

These are the future trends in technical institute education as I see them. Like all predictions they are subject to the whims of the future, particularly the international scene and the business cycle. Nevertheless, I believe that these six trends hold the significant clues to the future development of technical institute education in the United States.

Modern Engineering Physics from the Viewpoint of an Administrator*

By J. P. ABBOTT

Dean of the College, Agricultural and Mechanical College of Texas

Anyone who is asked to represent a viewpoint should, it seems to me, first make clear the point from which he proposes to do the viewing. If it does nothing else, this should reduce one of the hazards of discussion—the tendency on the part of all of us to proceed from what Justice Holmes called an "inarticulate major premise." Before looking at modern engineering physics, then, I ask you to consider with me the purpose of education. If this seems to you going around Robin Hood's barn to get to the subject, I can only plead that physics as a science and engineering as a profession are too important to the welfare of mankind to be considered solely, or even chiefly, from the point of view of the department of physics or the school of engineering.

For me the purpose of education—whether that of an engineer, a scientist, a business man, or any other—was never better defined than by John Milton in the *Tractate on Education.* "I call therefore a complete and generous education," Milton said in words familiar to you all, "that which fits a man to perform justly, skilfully and magnanimously all the offices both private and public, of peace and war."

In this conception of education, I believe, educators of all persuasions can meet on common ground. It is rigorously practical; in effect it says that education should prepare a man to do whatever he will be called on to do. It is at the same time liberal; it specifies that education shall prepare a man to do what he is called on to do in a manner in keeping with the most generous development of his powers.

There is a special appropriateness in reminding ourselves of Milton's definition whenever scientists and engineers meet to discuss problems of education. This definition was a sort of bench mark for those who helped draft the Morrill Act of 1862, and that Land-Grant Act was the motivating force behind the development of higher education as we know it today in our universities and technological colleges. The language of the Act itself specifically coupled "liberal and practical" in describing the kind of education that was to be fostered. As you know, the American Society for Engineering Education has consistently striven to preserve the marriage.

Major Premise

From this introductory analysis it is easy to move to my major premise as regards physics and the engineer. The engineering student, I submit, should be provided with such a knowledge of physics as he will need to do whatever he is called upon to do. (For the time being I omit any consideration of the manner of the doing, although I shall return to it.) I have encountered no one who is willing to take serious issue with this premise. Unfortunately, however, acceptance of the premise does not mean agreement on a program of action. Indeed, the same

* Presented at the Annual Meeting of ASEE, Physics Section, University of Florida, June 26, 1953, when the author was Dean of the School of Arts and Sciences.

premise is used to support the most widely divergent conclusions.

As I see it, much of the trouble derives from the fact that there is not yet a general agreement as to what the engineer will be called upon to do. After careful study, I am forced to conclude that *engineer* itself is an ambiguous term. It covers many distinct activities, each with a different set of offices to be performed. At one end of the scale there is the technician. At the other end there is the engineer-statesman. And in between there are designers, researchers, managers, constructors, and salesmen. What will best fit a man to perform as a designer will not necessarily best fit him to perform as a manager. A further complicating factor is that the same individual, at successive stages in his career, may be asked to fill the offices of a technician, a designer, a salesman, a manager, and a statesman.

That these facts have implications for engineering education is apparent to some members of this society. Mr. L. E. Grinter, in his "Questions Concerning the Engineering Curriculum" (JEE, January 1952), made them explicit. "The question to be raised," he said, "is whether we can provide the flexibility within individual curricula to take care of the diverse interests of designers, researchers, managers, constructors, salesmen and statesmen."

Physics and the other sciences are involved in this question. Flexibility may not be demanded of all engineering graduates. As Mr. Gordon S. Brown, Professor of Electrical Engineering at the Massachusetts Institute of Technology, put it, "Many [engineers] will be concerned wholly with bread and butter, or cookbook engineering rather than the advancement of technology. A sound education in the sciences is an unnecessary if not an indigestible luxury for a cookbook engineer . . ." (JEE, December 1952).

Some engineering faculty members enter a demurrer at this point. According to them, the analysis I have just outlined stems from an archaic conception of engineering education and simply perpetuates the discredited notion that the undergraduate curricula represent narrow job specialization. They say, further, that what is actually taught in the several curricula is fundamental and adds up to little more than the minimum knowledge necessary for any activity an engineer may have to undertake, whether it be design, research, construction, sales, management, or statesmanship.

Diversity of Careers

I acknowledge the demurrer and my own limitations as a judge. But it seems to me that the weight of the testimony from engineering faculties is as I have indicated. And if I am right, the problem of making our course offerings fit a diversity of careers must be faced, rather sooner than later. Perhaps, as more and more educators are suggesting, Professor Brown's bread and butter engineer should receive his education in a technical institute, with courses in physics, for example, tailored to his probable future needs as the user of engineering cookbooks. But a prior step, I suspect, requires the removal of any onus from this phase of engineering. The cookbook engineer is a valuable member of society, and should be so recognized. As a matter of fact, at least one director of industrial research has told me that the technician often makes a better member of a research "team" than does the professional engineer or scientist asked to serve under one of his fellows.

Leaving the technician aside, it may be that in the long run curriculum makers will decide to redesign engineering curricula to prepare for the functions enumerated by Grinter, rather than according to the traditional categories of mechanical engineering, civil engineering, and so on. Or, perhaps, a curriculum revision will take the direction of assigning special emphasis at certain institutions to the managerial phases of engineering, or to the research phases, or to the salesmanship phases. All these are possible, and each would modify a college administrator's viewpoint concerning engineering physics at his institution.

But there is another possibility which seems to me more promising. It stems from a growing recognition that in their more professional phases all the accepted divisions of engineering are moving closer to each other and to the basic sciences. Any reader of the *Journal of Engineering Education* is aware of the reiterated argument, in which men of diverse professional interests echo each other, for more basic science in the engineering curricula. One of the most persuasive spokesman is, as you know, Mr. S. C. Hollister, Dean of Engineering at Cornell University.

In an article entitled "Looking Ahead in Engineering Education" Dean Hollister said this: "It is clear that we cannot delineate sharply the various techniques that will be in use twenty-five years or fifty years from now; but it is certain that the principles on which these technical developments will be based are principles which are now available in the basic sciences. *Our problem, then, is to strengthen the basic science content of our curricula*" (JEE, December 1952).

Dean Hollister, like Milton, is concerned with fitting the engineer to perform offices not currently contemplated but almost certain to be thrust upon him. He has support from another source with an argument of more immediately practical impact. It comes from industry, where most engineers will be called on to fill whatever offices their lives will exact of them. Two quotations will document my point.

In the first Mr. Robert C. Sprague, President of the Sprague Electric Company, put it this way: "As an employer of more than 100 graduate engineers, I am among those who hold that the education of tomorrow's engineer should stress the basic sciences, even if this can only be done at the expense of applied engineering subjects." Mr. Sprague's reason is also, I submit, in keeping with the general principle I borrowed from Milton. "From my own observation," he goes on to say, "I find dramatic evidence that the man with the strongest basic training has the greatest adaptability. Because the basic sciences can be applied to different problems in many branches; or to a single problem which may extend into overlapping branches. In the rapidly changing technological industries such a man enjoys a tremendous advantage" (JEE, April 1953).

Fundamental Courses

The second quotation, similar in import, answers the strongest objection I have encountered to the increase of emphasis upon the basic sciences. It is from an article unequivocally entitled "The Modern Engineer Should Be Educated as a Scientist" (JEE, December 1952). The article is by Mr. Harry K. Ibrig, Vice-President in Charge of Research, Allis-Chalmers Manufacturing Company. In Mr. Ibrig's words, "It is often said that fundamental courses are all right for large companies that have training programs, but that small companies require engineers trained in specialties so that they can start work at once. One of the members of [A University Cooperating Committee of the Wisconsin Society of Professional Engineers] is a mechanical engineer who owns a small company manufacturing mechanical equipment. He believes that a broad fundamental training is very important in a small company where the engineers have to be versatile because the company cannot afford an engineer for each specialty."

It is clear to you by this time that my own idea of a generous education for the engineer is one that stresses the basic sciences, among which physics with its sibling mathematics is perhaps the most prominent. And my reason is that the emphasis upon basic science seems to me more likely than any other to fit an engineer to perform at least skillfully if not also justly and magnanimously the principal offices he will be called upon to fill.

I am, naturally, not alone in this belief. Indeed I would be reluctant to advance it so boldly if others had not also arrived at the same conclusion. There is a clear acknowledgment that physics deserves a

larger place in engineering education in the "Report of the Committee on Adequacy and Standards of Engineering Education" of the ASEE (JEE, January 1952). As the report says, "The time requirement in physics has remained nearly constant in most curricula since about 1885. Generally the classical approach to physics instruction has been followed . . . the approach from the point of view of atomic and molecular structure is needed but wanting."

What the time requirement should be I am not prepared to say. The Wisconsin Committee referred to by Mr. Ibrig has said that it is "very desirable from an industrial standpoint" to set the requirement at 33 hours in a total program of 144 hours. Since this is precisely the requirement set for all engineering subjects, I take it that this represents an extreme position and one not likely to be adopted by engineering schools in the foreseeable future.

My friends in the physics faculty of my own institution are more moderate. They believe that a time requirement of approximately 16 semester hours may be enough. In this time, they say, an engineering student can be led to understand the fundamental concepts of classical physics—dynamics, wave motion, heat, sound, light, and electricity, and can also be led to understand the extension of these concepts into the realm of atomic and nuclear phenomena. They are convinced that with this conceptual foundation the student can, if he will, carry his own education forward in whatever area of physical effects his duties may place him.

But at this stage of the discussion concerning the engineering curricula, it is probably premature to talk of semester hours. A more fundamental question needs to be answered first. Mr. W. S. Evans, Professor of Civil Engineering at the University of Maine, asks it in the April issue of the *Journal of Engineering Education:* "Are We Ready to Consider a Major Change of Policy?"

Curriculum Hours Limited

His own answer is that "we should hold the four year curriculum for those things which can best be taught in an institution of higher learning." This answer assumes, of course, that we will reject the possibility of extending the engineering program to five or more years. From my own observation I am convinced that in the majority of institutions the four-year pattern will continue to prevail. I do not know whether our schools of engineering are ready for Professor Evans' major change of policy. Since it will entail a complete revision of hallowed curricula and since I have great respect for the laws of inertia, I am inclined to think that any change will come slowly and in piecemeal modifications of existing course offerings. Professor Brown, whom I quoted earlier in this paper, recognizes that a knowledge of atomic physics and physics of the solid state is important to modern engineers. "But," he adds immediately, "the curriculum hours for teaching physics are limited."

Even with a fairly extensive revision of engineering curricula, increases in the amount of physics required of engineering students will almost certainly have to be accommodated to limitations of curriculum hours. Professor Brown suggests that a possible solution may be to turn over the teaching of much of the classical physics to engineering departments, where it will become an integrated part of engineering. This would leave the department of physics room to introduce a solid body of work in modern physics. The suggestion is certainly worth considering. The consideration, however, should be by both the physics and the engineering faculties, and they should be cautious of stopping short before they reach a consensus.

If the parenthesis is needed, let me say that I am not implying that departments of physics should necessarily be assigned more of the engineering student's time, but only that the conceptual bases of physics should be given a larger

place in his education. It may be true, as I am assured, that engineering courses are for the most part simply applications of physics and fundamental in nature. I am willing to accept the assertion that it is difficult to segregate physics and engineering, and to grant that it is special pleading to argue that the physics in a physics course is a basic science but the physics in an engineering course is not. But I do believe very firmly that physics, wherever taught, loses value for the student if its applications are permitted to obscure its concepts. And that is why I would have the physics and engineering faculties mutually agree upon a division of labors.

With this observation I reach a transition point in my survey. I have declared my conviction as a college administrator that engineering students, if we exclude those who aim at being hewers of engineering wood and drawers of engineering water, should be provided with a solid foundation in the basic sciences, among which I assigned a prominent place to physics, including the physics of atomic and nuclear phenomena. I based my case on the argument that such a foundation is the best assurance that the engineering graduate will be prepared to perform skillfully whatever duties he is assigned as a professional engineer. It remains for me to consider engineering physics in terms of Milton's other adverbs—*justly* and *magnanimously*.

Specialized Technical Competence

It may well be false to say that the engineer concentrates on developing specialized technical competence at the expense of all other considerations. But to the extent that it is true in any student's case, he has denied himself a generous education. "Born a man, died a chemical engineer," is a tragic epitaph, but no more tragic than "Born a man, died a physicist," or for that matter no more tragic than "Born a man, died a college dean." Even a moderate amount of specialization makes us subject to a common hazard of the times. Matthew Arnold described it in *Culture and Anarchy* when he said, "Faith in machinery is our besetting danger." We tend to put our faith in the machinery which we have seen operate successfully in our own areas of competence. And by extension of this understandable attitude, we tend further to put our faith in machinery itself. It may be the atom bomb; it may be a loyalty oath; it may be statistics; it may be this or that system in this or that sphere. In our discussion here it may be one curricular pattern rather than another. Faith in machinery of any kind is fatal to achieving the sort of education Milton defined. That education aims at making a man capable of taking all machinery in stride. Knowing that he may be confronted with a new model tomorrow, he is safe from idolatry of the current model.

I see, or think I see, a disposition on the part of many of us to put our faith in a piece of machinery which I personally admire very much. Mr. Irving S. Olds, recently retired U. S. Steel Board Chairman, puts it this way: "The most difficult problems American enterprise faces today are neither scientific nor technical but lie chiefly in the realm of what is embraced in a liberal arts education." As one whose formal education was nurtured in the liberal arts, I am happy that their place should be recognized and their estate acknowledged to be honorable. And I recognize the significance for the student engineer, who may someday be asked to assume managerial functions, of the warning issued by another industrialist, Mr. Sidney Swensrud, President of the Gulf Oil Corporation. Mr. Swensrud has said, "The men who come into management must understand the whole sweep of modern political, economic and social life." But I would be less than scrupulous if I did not warn all who are about to put their faith in a liberal arts education that it too is a machine, that its faculty may err on the side of idolatry like any other faculty, and that any model of it is subject to obsolescence.

It is obvious that some machines are better designed to achieve their purposes than others. I myself am convinced that our educational machine in engineering has neglected what the liberal arts could add to its efficiency of operation. But I would not have us substitute one machine for another in blind faith.

Like the drafters of the Land-Grant College Act, we would do well to return to our bench mark. Milton's definition makes no mention of any particular system of education. It favors no one discipline. It declares only that whatever system will prepare a man to do what he has to do in a fashion commensurate with his highest potential is a complete and generous education. This education, it says further, is *one,* not a compromise among competing systems or branches or divisions.

This sort of education has been prophesied for engineering. Last September at the Chicago Centennial of Engineering in a Symposium on Engineering Education and Training, Dean L. M. K. Boelter of UCLA made this prediction in his paper "Looking Ahead in Engineering Education": "Throughout the engineering educational process the complete growth of the student will be facilitated with the teacher as central. He will be encouraged to 'know himself,' to know others (and society), and to be a living example of the interrelationship between the physical and human worlds. For the student there cannot exist two stems (technical and social-humanistic) but rather a synthesis not only of the knowledge of the physical world but of knowledge itself" (JEE, December 1952).

May Take Several Shapes

As I have indicated, what shape the curriculum will take is as yet undetermined. It may, indeed, take several shapes. I think it is almost certain that physics will be given a larger place in every pattern. Physics will be judged, however, not alone by what it contributes to the skill of the student engineer, but also by what it contributes to his total development as a person. I think it can be made to contribute much.

In company with mathematics, the other sciences, and many of the engineering subjects themselves, physics can induce in the student an abiding respect for facts. This alone is a great contribution toward the student's full development. Respect for facts is essential to an apprehension of truth. As Mr. T. V. Smith, Maxwell Professor of Citizenship at Syracuse University, has said, "Science . . . is the one great organized, established way that the human race has found of developing scrupulosity in human beings." Scrupulosity, he goes on to say, is not an inherent quality. "It is an achieved capacity, for most of us would not know truth if we met it in the road. Yet we need people who know how to get it when we do need it; and that is the role of science" ("Middle-Sized Values for Higher Education," *Current Issues in Higher Education,* 1952).

The peculiar contribution of physics to the generous education of the student engineer, I am convinced, lies in its power to initiate him in the use of the mathematical instrument. This instrument, as A. d'Abro wrote in *The Evolution of Scientific Thought,* is capable of "giving us a deeper insight into the problems of nature, revealing unsuspected harmonies and extending our survey into regions of thought whence the human intelligence would otherwise be excluded."

As the student of physics proceeds from concept to concept, he can be led to see, in d'Abro's words, that "in order to render nature amenable to mathematical treatment, it is necessary that we should succeed in reducing the various natural phenomena to common terms." He can be led to the realization that usable knowledge begins with "seeking differences of quantity beneath differences of quality." Although I am not competent to carry the analysis to a rounded conclusion, I submit that the student who learns this lesson is well on the road toward preparing himself for the just performance of his duties whatever they be.

If it is to do these things, of course, physics must be properly taught, with a view to harmonizing its own peculiar contribution with the contributions of the other disciplines, to the end that the student's education will be an organic whole and not a collection of bits and pieces of knowledge. As Dean Boelter said, the teacher is "central." As a college administrator I can only deplore the attitude of some members of the physics faculty in many colleges. They regard the teaching of the basic undergraduate courses as a chore and their assignment to such courses as an imposition. The basic courses deserve the best possible teaching by the finest members of the physics staff. No physics faculty known to me would feel that it had carried out its responsibilities if its instruction aimed at developing in the student no more than an *ad hoc* knowledge of physical concepts and manipulative skill in their application. And every physics faculty, I think, would acknowledge that courses in physics should contribute to the student engineer's growth in habits of scrupulosity and devotion to truth. But how many direct their best efforts to this end? How many simply assume that the benefits will accrue automatically from contact with physics in the classroom? How many deliberately aim at making the basic physics courses a liberalizing experience? Only with the most devoted teaching can physics, or any other subject, become part of a generous education.

Conclusion

This completes my survey of engineering physics. The view has possibly been more panoramic than you would prefer. It is my hope, however, that if I have failed to bring new vistas to your attention, I have at least not fogged the landscape. All of us are seeking the same end, whether we orient ourselves on Milton's definition or not. That end, I take it, is to make every course contribute as fully as possible to the complete education of the student. If we keep that end in sight, our differences will become the means of exploring the alternative avenues of approach.

College Notes

Dr. John D. Ryder, head of the electrical engineering department at the University of Illinois, has been named Dean of the School of Engineering at **Michigan State College.** The appointment is effective July 1, 1954. Dr. Ryder succeeds Dean Lorin G. Miller who retired July 1, 1953. Dean Miller, a member of the staff since 1929, had served as dean since 1949. Following Dean Miller's retirement, Dr. A. A. Potter, retired dean of the School of Engineering at Purdue University, has served as consultant to President Hannah in charge of the School of Engineering.

The Undergraduate Course in Process Design

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Introduction

The instructor charged with the responsibility of teaching a course in process design to senior students in chemical engineering is faced with a serious problem in determining how the students' time can be utilized most effectively. The problem is particularly difficult in this course because of the breadth of the subject of process design, embracing as it does the fundamentals of chemistry, thermodynamics, unit operations, reaction kinetics, economics, instrumentation, etc. In view of the breadth of the subject it is not surprising that there exist widely divergent opinions as to the proper method of approaching the subject. As a matter of fact, it is undoubtedly true that there exist several satisfactory approaches to the subject, some of which will be effective in the hands of a given teacher and some of which will not.

It would be very helpful in planning the process design course if it were possible to state clearly the objectives of such a course. However, since process design is usually taught as a course requiring the student to bring to bear on a particular problem his previous knowledge of science, engineering and economics, the objectives of the process design course become identical with the overall objective of the engineering portion of a student's education. One way of stating this overall objective is to say that we attempt to develop in students the ability to apply to certain types of problems a particular type of reasoning process, having its origins in mathematics and the physical sciences but going beyond these because some of the problems require reasonable answers to be obtained in the absence of sufficient knowledge for a precise analysis. When a student enters the process design course he will have had a considerable amount of training in the solution of problems where precise analysis is possible. His approach to these problems will have been directed to a considerable extent since most of them will have been assigned to amplify certain well-defined lecture material or certain well-defined reading assignments. The student at this point is ready to learn several facts about the practice of the profession of engineering:

1. The practice of this profession does not consist merely of solving problems which have been stated by higher authorities but of stating as well as solving problems.
2. It is the engineer's responsibility to determine which portions of the available knowledge can be applied to a given problem and whether a precise solution to a given problem is feasible; i.e., to recognize when precise analysis must be abandoned in favor of approximation.
3. Some problems in engineering are so complex as to necessitate rather arbitrary decisions on how to proceed with a solution to the problem. Such arbitrary decisions may be completely justified when there are relatively minor differences in the methods of solving the problem.
4. Most engineering achievements of any magnitude are the result of cooperative efforts, frequently involving large numbers of scientists and engineers.

In process design as in no other course in the undergraduate curriculum there exists the opportunity to broaden the student's perspective and to indicate to him what he must do in order to become a successful engineer.

The time available for doing these things is limited, however, to about 150 working hours for a one-semester course or possibly 300 working hours for a two-semester course. Thus we have in the best case the equivalent of no more than eight 40-hour weeks to devote to this very important portion of the student's education. This appears to be totally inadequate in view of the further fact that this material can hardly be taught; it must be learned. It is not argued that more time should be devoted to this course but rather that the instructor must utilize the students' time very effectively.

The Scope of Process Design

The primary task of a process design engineer is one of synthesis, of bringing together the knowledge and opinions of scientists, engineers, economists and others and applying them to the problem of designing a plant. He is not merely one who accepts such knowledge and opinions in predigested form. Instead he must work closely with these other groups in building up the required knowledge, making certain that research and development groups provide the essential data for process design and frequently, because of economic considerations, making certain that they provide no more than the essential data. It is also his task to analyze all data and all opinions critically since he has the ultimate responsibility of applying these in such a way that a workable design results. These several functions place the process design group in a key position, acting sometimes in an advisory capacity and again assuming the major responsibility.

Consider that the statement of a problem in process design must be developed over a period of months or years as the result of the activities of several groups of people. Thus in the development of a new product the following steps might be involved:

A. Survey of literature
B. Survey of markets
C. Basic research and development
   1. Choice of a process
   2. Raw materials specifications
   3. Product specifications
D. Preliminary layouts, cost estimates, etc.
E. Plant location
F. Plant layout
G. Final design and economic analysis
H. Plant construction
I. Plant start-up
J. Plant operation

One usually conceives of such a development as occurring essentially in chronological order and involving shifts in responsibility from research to development to design groups. This picture is essentially correct but there is also involved a great deal of cooperative effort, and many of the activities listed occur more or less simultaneously.

For example, the process design group may be called on to examine a project after the surveys of literature and markets are completed. There may be enough information available from these two sources to permit a preliminary design and cost estimate. The results of this preliminary design and cost estimate may indicate that the proposed project is not economically feasible, in which case it would not enter the research and development laboratories. If the process appears to be feasible at this point it is apparent that the process design group can perform a very important function in advising the research and development groups as to which portions of the process require further investigation. As research and development proceed it may be necessary for the process design group to evaluate their results periodically, advising whether a particular method of

attack should be continued or not, advising when the data are adequate, etc. This may be one of the most difficult tasks of a design engineer since considerable diplomacy may be necessary in explaining to a development engineer that one of his pet ideas is not economically feasible. For example, if the equipment for a particular process is available for a price of $100,000, it would be difficult to justify a $25,000 development program in the hope of reducing this cost to $60,000 unless the problem is one which might occur frequently in the future, no matter how ingenious the proposed solution might be.

It is to be noted that during steps A, B and C of a development such as that outlined above the function of the process design group is an advisory one. It is not intended to imply that all of the work done by research and development groups is subject to appraisal by the process design group since the engineers and scientists in these former groups have much broader functions. After the first three steps of the development are completed, however, the process design group assumes the major responsibility for the plant location and layout, final design, supervision of construction and plant start-up.

In many cases the responsibility of the process design group ends when the plant is operating satisfactorily and operators have been adequately trained. This group may be called back to other problems, however, if economic conditions lead to the necessity for production above the design capacity, for the recovery of by-products, for changes in product specifications, etc.

The breadth of activities of a process design engineer may also be indicated by noting that he may spend a large part of his time in stating problems rather than in solving them. The definitions of the problems which may be of interest to the process design engineer may be summarized as follows:

Problem type	Raw materials	Process	Products
1	Unspecified	Unspecified	Unspecified
2	Given	Unspecified	Unspecified
3	Unspecified	Unspecified	Given
4	Unspecified	Given	Given
5	Given	Unspecified	Given
6	Given	Given	Given

The very broadest problem with which a process design engineer is concerned arises when an organization has capital to invest in a chemical enterprise and seeks advice as to product, process and raw materials (Type 1). It is probably more frequently the case that advice is sought as to how to utilize a given raw material (Type 2) or how to manufacture a given product (Type 3). It may also be the case that a desirable product and process are known and the problem is one of choosing appropriate raw materials (Type 4), or that the raw materials and products are specified but the process remains to be chosen (Type 5). Before a final design can be undertaken it is necessary that the varied activities of several groups be so coordinated that the problem becomes completely defined (Type 6) as to these three factors.

The varied activities of a process engineer, as depicted briefly above, make this type of position one of the most thoroughly fascinating ones in the field of chemical engineering. As in all other cases, reaching a position where the full challenge of the field is met requires an apprenticeship in each of the several phases noted. These apprenticeships will cover a period of several years before the full-fledged process design engineer emerges. The decision of the individual student as to whether he should enter this field depends on an honest appraisal of his abilities, interests, physical stamina, ability to work under pressure (or to "think on his feet") and personality characteristics.

Methods of Teaching the Process Design Course

The process design engineer has been depicted as one who must understand all phases of a chemical development, functioning at times in an advisory capacity, and assuming active charge of the project after the cooperative efforts of his own group and the research, development and management groups have stated the problem clearly. It may be noted that a somewhat similar picture could be painted of the activities of the research and development groups since each of these groups functions in an advisory capacity both before and after the major responsibility has passed its particular interests. It is in the process design course that there exists the best opportunity to indicate to students the roles played by each of these groups, thus making the course of great value to the individual student whether or not he enters the field of process design. Perhaps one of the most common failings of young engineers is a failure to appreciate the contributions made by groups other than the one with which he is associated.

We are obviously now in a position to say that the process design course preferably consists of a project in miniature, carrying a process through all phases of its development from the market survey to the final design. The course is taught in just this way at several schools, the students devoting their attention first to literature and market surveys, then to research and development work in the laboratory and finally to the detailed design. This type of course is undoubtedly very effective in the hands of an inspiring teacher and represents a logical approach if sufficient time is available for it. However, it has been noted above that the time ordinarily available is no more than the equivalent of eight 40-hour weeks of student time. In order to obtain definite results in this short period it is necessary that the process chosen for the work be quite simple or that the instructor guide the entire development rather carefully. If the process chosen is too simple the students are likely to lose interest rapidly; if it is too complex their interest will wane because too many approximations will be necessary. If the instructor guides the work too closely the students lose the opportunity of using initiative. Thus for this type of course to be successful the problems must be chosen with extraordinary care, and the instructor must be very careful in his guidance of the work.

The author is inclined to favor a second type of design course which may be said to consist of developing the complete statement of a problem together with a partial solution. If the goal of a complete problem solution is abandoned in favor of this approach it becomes relatively easy to devise problems which preferably have the following characteristics:

1. The statement of the problem is very broad, requiring that the students restate it and amplify the statement as they proceed.
2. Some portions of the problem are such that precise analyses are possible.
3. Some portions of the problem are such that precise analyses are not possible but approximations can lead to adequate solutions.
4. Some portions of the problem are such that neither precise analyses nor satisfactory approximations are possible in the absence of further experimental data.
5. The process on which the problem is based is sufficiently complex that the student's interest is held throughout the course.

A particular problem used by the author in teaching the process design course will serve to illustrate the basic philosophy used. The problem may be stated as follows to the students:

We have been requested by the management of Sachem, Inc., to provide a preliminary report on the design of a plant for the chlorination of methane. The client has available a satisfactory source of natural

gas (typical analysis: 92.1% CH_4, 1.9% C_2H_4, 4.5% C_3H_8, 1.5% C_4H_{10}) and is in position to purchase chlorine from an adjoining plant. We are informed by the client that his market survey group has estimated that there would be a market for the following annual sales of the products of this plant: 1000 tons CH_3Cl, 1000 tons CH_2Cl_2, 3000 tons $CHCl_3$ and 5000 tons CCl_4.

For the preliminary report we may consider that our task is one of developing a complete flow sheet, designing those portions of the equipment where adequate data and calculation method are available, and making recommendations as to the general problems which must be solved in the laboratory before a final design is undertaken. This will be sufficient information to permit us to make very rough estimates of the costs involved.

The students are required first to survey the literature for methods of carrying out the reaction between methane and chlorine. A class discussion following this survey leads to a somewhat arbitrary decision to proceed with the design on the basis of a particular type of reactor but it is emphasized that this decision is subject to review at a later date. The students are expected then to recognize the existence of the following specific problems:

1. Either the natural gas must be purified before chlorination or a very complex mixture of chlorinated hydrocarbons must be separated after chlorination.
2. The estimated sales volumes indicated are subject to considerable error and to constant changes with varying market conditions.
3. In view of the indication in (2) and of the fact that a group of consecutive reactions is involved it will not be possible to adjust the methane-chlorine ratio in the feed to yield a product stream containing only hydrogen chloride and chlorinated hydrocarbons. Either an excess of chlorine or an excess of methane must be used.
4. There will be numerous schemes for the separation of the products of reaction.

The answer to the first problem above is obtained readily when the removal of ethane and higher hydrocarbons from the feed by absorption is compared with the task of separating a complex mixture of chlorinated hydrocarbons by rectification. There are available adequate physical data and calculation methods to permit design of the absorption equipment. The answer to the second problem above lies in a close study of the variables which determine the product distribution. It is not feasible in the undergraduate course to design the reactor system completely but it is possible to decide on the reactor arrangement and to calculate material balances and heat balances. The reactor will have to be "blocked in" for the purposes of a flowsheet unless the instructor desires to guide the calculations carefully. The answer to the third problem lies in a comparison of the difficulty of separating either unreacted chlorine or unreacted methane from the product stream. There are sufficient data and calculation methods available to obtain reasonable answers to the problem of designing the equipment for the separation of products although the students will need some help in calculation methods.

The result of several weeks of work by the students on a problem of this type will be a preliminary flow sheet with complete heat and material balances, with a few pieces of equipment designed at least to the extent of sizing them, and with a few problems stated as needing laboratory investigation. The students will have come to recognize something of the difficulty of stating a problem and they will have used precise analyses in some cases and approximations in others. Most of all, they will have realized something of the spirit of process design.

Finally, there remains the possibility of teaching process design from the other end of the development scheme; i.e., by giving the students a completely formu-

lated problem in which their task is the final layout and design. The author has tried this approach and found it interesting and instructive. It is, however, more difficult to hold the students' attention because of the numerous rather minor details which must be considered. Furthermore, this type of problem is likely to lead students to the conclusion that process design is a field for the patient ones whereas it actually involves so many factors other than final designs that it should be appealing to several types of students. There will be some teachers who feel that this type of course offers excellent training in discipline because of the numerous details involved. Actually, of course, any problem of sufficient scope will offer such training.

Conclusions

There have been presented the author's viewpoints as to the proper nature of the process design course for seniors in chemical engineering. The teaching method suggested is, however, only one of at least three logical methods of teaching the subject. A critical examination of these three presentations of the subject will reveal that the objectives of the process design course can be achieved through any one of them provided that the problems are properly stated and that the instructor provides only the minimum guidance necessary in developing the problem statement and solution.

Perhaps the most important points in the author's presentation are:

1. Process design should be presented not as a drafting table enterprise but as an enterprise involving many factors and requiring that the engineer be not only technically proficient but also skilled in the art of personnel relations.
2. The interest of the students can be held more easily if the goal of a complete and detailed design is abandoned in favor of problems involving the development of a complete statement and a partial solution to a problem.
3. A considerable part of the course should be devoted to the devising of a flow sheet and to analyzing problems to determine where precise analysis is possible, where approximation is necessary and where research or pilot plant programs should be considered.

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Graduate Education in Engineering

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A. Introduction

The question of what type of graduate education is of most benefit to an engineer may be approached by reviewing briefly the history of engineering during the past twenty years. More specifically, I shall confine myself to aeronautical engineering. It has been my own experience during this time that the only engineering courses which have been of any use to me have been the courses dealing with the basic engineering sciences. Everything we learned in highly specialized courses in various phases of engineering has been rapidly obsoleted by new developments. The biplane truss design has been replaced by monocoeque wing design; the reciprocating engine has been replaced by the gas turbine; the wooden structures have been replaced by dural, steel, titanium and glass cloth laminates; the manual controls have been replaced by hydraulic, electric or pneumatic servos and gyroscopic autopilots. Thus, the proposal which I should like to make is that the primary emphasis in graduate, as well as undergraduate, education in engineering should be devoted to teaching the engineering sciences, thoroughly and clearly, illustrating the principles by application to modern engineering systems, demonstrating the principles with simple laboratory models, and giving the student practice by realistic design problems. It is my belief that since the time available in post graduate education is limited to, at the most, two or three years, the time devoted to highly specialized and applied courses should be restricted to a minimum. These specialized subjects should be preferably taken as extension division courses after the student is engaged in engineering practice and has a need for specialized knowledge dealing with his type of work. It is my belief that the detailed design tricks can best be learned by an engineer after he is engaged in a given field, and that the so-called "art of engineering" or the design of a complicated engineering system cannot be taught in the limited time available in school without slighting the essential engineering sciences. This "art of engineering" would therefore be acquired as the result of engineering practice by building upon a sound foundation of the engineering sciences.

B. Aeronautical Developments

Let us review briefly the history of aeronautics during the past twenty years in order to illustrate the above ideas.

(1) Aircraft propulsion

The increase in airplane performance during the past twenty years has been largely paced by the development of powerful and light aircraft propulsion systems. Table I shows the relative performance of typical high performance powerplants of 1933 and 1953. University courses in aircraft powerplants in 1933 were of little help in the design of centrifugal or axial flow compressors or the burners for gas turbines or the combustion chambers for rockets. These new propulsion systems were developed largely by the application of aerodynamic prin-

TABLE I

RELATIVE PERFORMANCE OF AIRCRAFT PROPULSION SYSTEMS WEIGHING 2,000 LBS.

Year	Type	Max. Aircraft Speed, V	Thrust, F	Thrust Horse-Power, $P = \frac{FV}{550}$
1933	Reciprocating Engine and Propeller	V = 450 ft./sec.		1,000 H.P.
-1953-	Turbo Jet	V = 1100 ft./sec.	F = 6000 lbs.	P = 12,000 H.P.
	Rocket	V = 5500 ft./sec.	F = 100,000 lbs.	P = 1,000,000 H.P.

ciples to the design of compressors, burners, and turbines. The basic laws of thermodynamics and heat transfer, of fluid dynamics and elasticity were of much greater help in the design of these systems than the prior art in the field of aircraft engines.

(2) *Aerodynamics*

With the increase in power, aircraft and missile speeds have increased about tenfold during the past twenty years. The biplane with its external bracing was replaced by mono-planes with streamlined cowlings, retractable landing gear, laminar flow wing sections, and more recently, by the thin swept back wings or delta-wings with a capability of flying at transonic speed and supersonic speed. The traditional aerodynamics courses of 1933 offered little help in the solution of these problems. They presented a summary of past experiences on lift, drag, and pressure distributions on various bodies for an incompressible fluid. Only a few exceptional universities offered courses in hydrodynamics covering the basic theory of boundary layers and turbulence, the theory of wings including low aspect ratios, the fundamentals of gas dynamics including transonic and supersonic flows. Very few aerodynamics courses included rotary-wing aircraft or the theory of wing flutter or the dynamic analysis of aircraft systems.

(3) *Aircraft structures*

With the increase in aircraft speeds, the aircraft structures have also changed radically. In 1933 the most common aircraft structures were of a wood or steel framework and a doped fabric skin covering. At about this time the monocoque or shell structures were introduced. The standard aircraft structures courses were rather inadequate for dealing with the problems of buckling of flat and curved panels in bending, compression and shear. The theory of elasticity including the theory of shells and plates on the other hand, offered a good background for tackling these new problems. Present thin aircraft wings are almost solid plates with swept-back or delta shaped plan forms. The analysis of these wings particularly from the dynamics and flutter standpoint, represents one of the current challenges of structural design. Again, the only tool for the young graduate in this field is a good understanding of the fundamentals of elastic theory and dynamics. The new types of structures currently under study for use at the high temperatures of supersonic flight—glass-cloth laminates or ceramic structures or combinations of these with metallic structures—will require an understanding of the elastic theory as well as of heat transfer and thermodynamics.

(4) *Aircraft system engineering*

The above mentioned examples are illustrative of the type of problems faced by the aeronautical engineer during the past twenty years and now being faced for the future. It was found by experience that the descriptive courses in various phases of aeronautics might help

young engineer in his first years of industrial practice. They did not equip him, however, with the tools for starting out on a fresh approach.

The most serious problem which is encountered in a modern aeronautical engineering department is the scarcity of engineers with a good background in the various basic engineering sciences. They will ordinarily have studied a limited field like aerodynamics or propulsion or structures, or radar, or servo-mechanisms. However, there are very few with a good understanding of the fundamentals in all of these fields. As a result, the "systems engineering" which means making the compromises between these various elements is usually not carried out too well. This "systems engineering" which is what is sometimes called the "art of engineering" can not be taught without teaching first the engineering sciences. A graduate who has a thorough grasp of the engineering sciences basic to his field of activity will be able to develop the "art of engineering" simply by applying his common sense.

C. Engineering Science vs. Physics as Preparation for Engineering

It has been argued by some educators that the best graduate preparation for a career in engineering is graduate study in physics, chemistry and mathematics. It is my impression that an outstanding young physicist can learn to tackle engineering problems just as an outstanding young engineer can learn to solve problems in physics. However, there is a considerable difference in emphasis between the engineer and the physicist or the mathematician in his outlook and his approach to a given subject. For example, a classical physics text on dynamics presents the basic theory of vibrations of systems with various degrees of freedom. An engineering study of vibrations starts from this point and illustrates how it is possible to reduce complicated physical problems such as the forced vibration of an engine crankshaft, or the flutter of an airplane wing or the vibration of a turbine blade to simplified differential equations which can be solved by approximation methods or with the aid of analog or digital computers. Similarly, a classical physics text on hydrodynamics contains the mathematical theory of fluid motions. An engineering study of hydrodynamics takes this same theory as a starting point but concentrates on the application to wings and airfoils, to skin friction and turbulence, to shock waves and boundary layers. Similarly different viewpoints apply to the theories of elasticity, electricity, and magnetism.

We may approximately summarize this situation by stating that the standard physics courses and texts concentrate on developing the fundamental principles of physics and stating them in a simple mathematical form, that the engineering science courses and texts concentrate on the applications of these principles and equations to engineering problems. Thus, to the physicist, elegant methods of deriving and summarizing the equations (such as vector, tensor, and matrix methods in elasticity, or Lagrange's equations and Hamilton's principle in dynamics) are of considerable importance. To the engineer the principal problem is to reduce a very complicated physical situation to a simplified model, which he can think through and understand with the aid of the mathematical equations and which he can analyze with the aid of simple approximations with the aid of digital or analogue computers, or with the aid of model tests and experiments. Obviously, there is a considerable region of common interests. The best physics texts such as, for example, Sommerfeld's series of books on Theoretical Physics, cover much of the same ground as books or papers on the engineering sciences by von Karman and Prandtl, Timoshenko and Den Hartog, Biezeno and Grammel. It is my belief, however, that courses in physics are not a substitute for the related courses in the engineering sciences but rather, a supplement and that therefore, the engineering sciences should be taught as such by "engineering scientists"

who know the practical problems of engineering as well as the applicable basic sciences.

D. Recommended Program of Graduate Courses

I have attempted to think through the kind of a graduate program of courses I should like to take if I had the opportunity of starting over to prepare for a graduate degree in engineering. This program would be most suitable for aeronautical or mechanical engineering but a similar program would also apply to the other fields of engineering. The program would consist fundamentally of four basic courses in engineering science each year. Each course would consist of three lectures per week plus an afternoon of laboratory work or problem discussions. A candidate for the Ph.D. degree would, in addition, include about two related graduate courses in a physical science plus a thesis. In addition, the engineering school would offer specialized courses in its extension division as optional courses for those students who desired such specialized training in a particular field.

It is proposed that such a program would consist of:

Two Years—Applied Mathematics
Including vector analysis, Laplace transforms, and other math. methods.

Two Years—Fluid Mechanics
Including hydrodynamics of perfect fluids, the theory of wings and airfoils; viscous fluids; boundary layers, and turbulence; compressible fluids; gas dynamics; stationary and nonstationary flows.

Two Years—Structures and Theory of Elasticity
Including theory of elasticity and plasticity; theories of strength; buckling; shells and plates.

One Year—Dynamics
Including mechanical vibrations of machines; flutter; dynamics of aircraft and missiles.

One Year—Thermodynamics and Heat Transfer

One Year—Survey: Modern Physics for the Engineer
Substantially covering the subject matter of U.C.L.A. course by the same title.

One Year—Applied Electronics

The graduate student working toward a Ph.D. should learn the methods and techniques of engineering research in preparing his thesis under the supervision of an experienced faculty advisor. It is very desirable that the thesis include experience with both the analytical and experimental methods of engineering research. In addition, the graduate students should obtain experience in presenting the results of his research work orally before an audience in a weekly research conference and at least once a year, by presenting a seminar. Such practice in public speaking on engineering topics, if criticized constructively by the audience, is of much more help to an engineer in learning to express his ideas than the formal courses in public speaking.

E. Extension Division and Specialized Courses

Most engineers can not anticipate the exact field of engineering in which they will be active after they leave the university and therefore, it is recommended that highly specialized subjects generally be studied by the engineer after he is engaged in his professional practice. This may be done either with the aid of text books or extension division courses at a neighboring university. Thus, a mechanical engineer who is engaged in the design of gas turbines would do well to supplement his basic engineering science studies with a course in jet propulsion or in turbo-machinery. A course in jet propulsion would include the basic theory of steady and nonsteady flow jet propulsion systems in air as well as in water. A course in turbo-machinery would include a survey of the theoretical methods and the experimental data available for the design of axial flow compressors and

turbines, radial flow compressors and turbines, etc. If he is engaged in the design of combustion chambers for gas turbines, it would be to his advantage to take extension division courses in the theory of flames and combustion including a summary of the aerodynamic as well as the chemical aspects of this problem. If he is engaged in the design of regulators and controls for gas turbines, the mechanical engineer would do well to take extension division courses in servo-mechanisms and automatic control systems. If he has had a good program of courses in the engineering sciences, it is very simple for him to assimilate the subject matter of these specialized courses rapidly and to be in a position where he can make new contributions based upon his knowledge of the fundamentals.

The instructors for these extension division courses should ordinarily be outstanding engineers engaged in the practice of engineering. They will know much more about these advanced fields of engineering than any instructor at the university could be expected to know unless the latter is devoting a considerable portion of his time to research or to professional consultation with an engineering group active in this field. It is generally impossible for any instructor at a university to keep up-to-date in the details of various new fields of engineering development and consequently, the device of utilizing practicing engineers to teach these subjects is almost the only practical method for rapidly introducing these subjects into a university curriculum. The extension division courses taught by professional engineers offer at the same time, an excellent opportunity for the professor teaching a related engineering science to be kept informed of new technical developments and to introduce problems, demonstrations and new developments from these extension division courses into his own courses in the basic engineering sciences and to keep the basic engineering science courses lively and interesting.

F. Improvement in Engineering Instruction

The success of an engineering school in developing outstanding graduates depends primarily upon three factors: (1) Excellent physical facilities including buildings, laboratories, and research equipment; (2) A faculty composed of outstanding engineers with competence in both the teaching and the practice of engineering; (3) A capable group of students selected for their qualifications for engineering. The order of importance is in the reverse order to that listed. These conclusions also apply to graduate education in engineering.

In order to improve the caliber of the graduate students, it is suggested that the most qualified B.S. graduates in engineering be encouraged to continue graduate studies in the engineering sciences. It is suggested that engineers within the upper quarter of their graduating class continue for one or two years of graduate study towards a Master's or Professional Engineering degree; that the top ten per cent be encouraged to continue their studies toward a Ph.D. degree. It is recommended that most of these graduate studies be concentrated on the engineering sciences, and that the student usually defer highly specialized courses until after graduation.

It is recommended that the graduate faculty of engineering be selected from among the top one per cent of engineers in competence and with at least ten years of engineering experience. It is also recommended that the salary for these members of the engineering faculty be comparable with that paid to the top one per cent of the engineering profession. In order to maintain their technical competence, it should be expected that this graduate staff devote about twenty per cent of their time to engineering research or engineering practice.

It is recommended that the instructors in the specialized courses taught in the Extension Division be selected from among the best professional engineers en-

gaged in industry in the particular subject. These instructors in the Extension Division would normally devote about eighty per cent of their time to engineering practice and twenty per cent to teaching. In this manner, the most advanced fields of engineering development would be presented at the university by the real experts without making it necessary for the university to establish large associated development projects in every branch of engineering.

By this dual approach of having the basic engineering faculty devote about twenty per cent of their time to engineering research and development and conversely having outstanding practicing engineers devote about twenty per cent of their time to teaching specialized subjects in engineering, it would be possible to bridge more effectively the gap between engineering school and the engineering profession.

In order similarly to bridge the gap between the engineering school and the university departments in the basic physical sciences, it is recommended that students in the physical sciences be encouraged to take related courses in the engineering sciences and conversely. Each of these departments should, however, respect the different interests of the other and it should be recognized that the courses in engineering science do not displace the related courses in the physical sciences and conversely.

G. Summary and Conclusions

In summary the following recommendations are made to improve graduate education in engineering:

(1) Graduate as well as undergraduate instruction in engineering should be devoted to teaching the engineering sciences, thoroughly and clearly, illustrating the principles by application to modern engineering systems, demonstrating the principles with simple laboratory models, and giving the students practice by realistic design problems.

(2) Highly specialized subjects should preferably be studied by an engineer after he is engaged in this professional practice. He can then concentrate on the courses of direct interest to his field of work. These specialized courses should therefore preferably be offered by the university at its Extension Division in the evening. Mimeographed copies of such lectures should be made available by mail to engineers who cannot attend the university.

(3) Engineering students within the top quarter of their class should be encouraged to undertake graduate study in the engineering sciences. Students within the top ten per cent of their class should be encouraged to continue toward the Ph.D. degree in Engineering Sciences.

(4) The faculty for a graduate school of engineering should be selected from among the top one per cent (in competence) of engineers engaged in each field. They should have at least ten years of experience in engineering practice or research. They should be encouraged to continue to devote at least twenty per cent of their time to engineering practice or research. Their total salary should be comparable with that of the top one per cent of engineers (in salary).

(5) Instructors for specialized courses of the Extension Division should be selected from among the best professional engineers engaged in industry in the particular subject.

(6) Industrial managements as well as the engineers in industry should recognize that in order for an engineer to maintain his technical competence, it will be necessary for him to keep informed of the newest technical developments by such methods as extension division courses or independent study. Such supplementary studies should be encouraged.

Teaching Statistics to Engineers

By WYLLYS G. STANTON, SR.

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The problem connected with teaching statistics to engineering students and to men who were graduated from curricula which did not include statistics courses is already very important and it is constantly growing more so. A recent survey by Dr. Ralph M. Barnes, Chairman, National Curriculum Committee of the American Institute of Industrial Engineers, reported in the November 1953 *Journal of Industrial Engineering*, shows that 18 of 20 schools responding require at least one course in statistics. This is in contrast with the situation in 1946–47 when only eleven schools had such requirements in engineering curricula. Moreover eight of the schools have increased their requirements in statistics and six reported that they would like to make further increases by 1955–56.

What is behind this trend? In part it may be explained by a natural growth in the use of statistical presentations for the selling of engineering projects. One of the finest examples of this is the report prepared by the Ohio Highway Department to show the need for additional road building funds and how they are to be allocated. Another point is that the public is steadily becoming more sophisticated in statistical matters. Witness the alacrity with which critics claimed inadequacy and nonrandomness of the sampling in the second Kinsey report. Engineers have long made use of traffic counts, censuses of populations to be served by various kinds of public utility ventures and expansions, and other statistical procedures, but in the future they are going to need to be better trained, to state confidence limits with respect to their averages and to make other refinements. Refinement in the use of statistics has also been accelerated by the growth of industrial engineering with its emphasis upon statistical quality control, job evaluation, methods analysis and production control. Finally, the experience with controlled materials plans, with the necessity for furnishing all sorts of reports to the government, has greatly increased interest of all engineers in statistical methods.

Important Reasons

Cogent as the foregoing reasons may be there are three other very important reasons for including statistics in the training of every engineering student from this point forward. First is the realization, as instrumentation has improved, that measurements which were once accepted as definite values are only approximations or samples from the whole population of possible readings that might be obtained. Also it is ever more widely recognized that the classical experimental pattern of allowing only one factor to vary at a time completely neglects the important effects of interaction, and that a factorial design is much more fruitful, as well as more economical.

A second point is that engineering work must of necessity include a great deal of computation. Most engineering curricula contain courses designed to teach the use of the slide rule and to convert logarithms from a novelty in algebra courses to a practical working tool, but these courses come early and often there is inadequate stimulus to continue practicing the skills acquired until they become habitual and

automatic. It is true that some courses in mechanics and design aid in further development of computational skills but there is need for more work along this line. Statistics can scarcely be taught without including the working of many problems by the student and they can be designed to yield additional practice in computation as a valuable by-product.

A third and perhaps most important point is that the advances made thus far in the application of statistical methodology to engineering are only a token of those that are yet to come. The only way that they can come about, however, is by having a large body of engineers sufficiently trained in statistics to recognize possibilities and to cooperate intelligently with the professional statisticians who stand ready to help them. In some large laboratories, as at General Electric, statistical departments have been established on the premise that complete mastery of statistics and the development of new techniques, is in itself a life time career. Until the rank and file of engineers are sufficiently well acquainted with the rudiments of statistics to discuss their problems intelligently with these specialists the fullest possible cooperation and progress cannot be attained.

Differences in Statistics for Engineers

The natural question at this point is: what, if any, are the differences between teaching statistics to engineers and teaching it to other students? It is true that in many schools statistics instruction for engineers is handled on a service basis by the mathematics or other departments, often along with students from other colleges. From the point of view of an engineering educator this plan leaves much to be desired.

Engineers are much more sophisticated from a mathematical point of view than many of the students from other colleges. Use of a text which states that it presumes no knowledge beyond elementary or even college algebra, is unappealing to students who have had an introduction to the calculus. On the other hand more advanced texts which state that they are based upon nothing more difficult than elementary differential and integral calculus often make demands that the student is not prepared to cope with. Courses of this type may put engineering students in competition with mathematics majors, some of whom are preparing to be professional statisticians, and discourage them with work in series, matrix algebra, and multi-dimensional space.

Engineering students tend to approach their studies in an air of pragmatism which causes them to respond best to problems dealing with engineering data. We may deplore their lack of interest in studying a subject purely for the sake of intellectual development, and we may endeavor to steer them into more purely intellectual pursuits, but at the same time we do well to sugar coat the pill and to offer courses especially tailored to make the maximum use of their equipment and desires.

Because of the training in drawing and other courses engineering students are conditioned to accept and profit by a maximum of graphical presentation. Much of statistical theory can be treated graphically with profit for students who are properly prepared, and at the same time such presentation would be wasted upon students who do not have well developed traits of structural visualization.

Need Efficient Handling

The majority of all engineering curricula are so firmly packed with courses requiring a lot of work on the part of the student, that there is need for maximum efficiency in handling statistics, or any other course for engineers. The realistic instructor knows that he must compete keenly with other courses to obtain a fair share of the student's time. For this reason a course paced to suit the more leisurely gait of an arts college might be completely out of place for engineers.

In general engineering studies are held together by a strong chain of logic, and the student discovers early that he must

master a field step by step or be forever plagued by the gaps unfilled. In history on the other hand one can learn well the chapter on Henry VIII even though he skipped the one about William the Conqueror. Of course the understanding of the former will be enhanced by a better knowledge of the latter, but the omission it not fatal. For this reason engineering students require a course in which topics are built upon one another with care.

Although as stated earlier, there is increasing realization that physical measurements are far from exact values, this awareness has not fully penetrated many engineering college laboratories. Therefore in teaching statistics to engineers it is necessary to stress the variability of data more than it might be with a class of psychology students who are conditioned to expect wide variations in test scores or other experimental data.

Suggestions for Teaching Statistics to Engineers

Many of the suggestions to follow have already been implied in pointing out the difference between engineers and other students with respect to the study of statistics; still it may be profitable to restate them specifically.

1. Use a step by step development of theory together with the liberal use of demonstrations including actual physical apparatus.

2. Require students to work out enough mathematical proofs to make them appreciate that there is a rigorous basis for everything they are taught to do, but do not pursue this line so far as to take up time that may be better used to introduce other topics.

3. Use problems based upon engineering data. Although measures of central tendency, dispersion, skewness and kurtosis can be learned as well by manipulating a series of psychological scores, the engineer gets more meaning out of the problem if the data is a series of breaking strengths of test pieces.

4. Insist upon neatness and approved form in doing the written work. Encourage the use of tabular arrangements rather than a series of equations. Require proper rounding off of continuing decimals, and establish numbers of significant figures appropriate to the data at hand.

5. Develop problems which contain a minimum number of items adequate to illustrate the principle being studied. In too many texts problems are found which require hours of laborious arithmetic and do not teach any more than a simple problem would. Of course when teaching the method of collecting a series of readings into classes in a frequency array a large number of items is essential. Also it is desirable to have some problems based upon actual data in order that the students do not develop a feeling of unreality, but it is possible to greatly reduce the amount of drudgery often connected with statistics courses without any loss of theory.

6. After eliminating unnecessary work from problem solving, assign frequent problems.

7. Give frequent interim examinations, for experience indicates that they are probably more needed in statistics instruction than in most other subjects. All of the usual reasons apply here; revealing his own weaknesses to the student, indicating to the instructor how well he is getting the ideas to the students, giving the students a sense of accomplishment and encouragement to proceed, etc.

Growing Need for Instructors

There is little doubt that there is an insufficient number of men available to meet the growing need for instructors to teach statistics to engineers. That is to say that there is an insufficient number of men with complete and rigorous training in statistical methods. This is not as bad a situation as it might appear to be at first glance because the greatest need is for instruction in elementary and intermediate statistical methods. If this need can be met the smaller number of teachers needed to handle the few who go on

for advanced training will also be found. In fact it is at the higher levels that it may be expedient to turn the job over to the mathematics or statistics department.

Any good engineering instructor can readily learn enough statistics to handle a class in the elementary phases of the subject. By reading two or three good texts simultaneously he will obtain different viewpoints and a breadth of understanding that would not be possible to a reader working with only one book. By simultaneously is meant to take a particular topic e.g., calculating averages, and find out how it is treated by different authorities. This together with working out many problems will equip one to start the teaching of basic statistics, then classroom contacts will increase one's understanding rapidly.

Educational Research May Aid Engineering Teaching

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One of the dramatic changes which has occurred during the past generation is the emergence of specialization, especially in the professions. This specialization has its roots in the rapidly growing volume and complexity of the information and techniques encompassed by any field of work. The advantages accruing to society from the deepened insights and skills of those who specialize are of course profoundly significant. The difficulties, perhaps not so obvious, are none the less important.

Of the difficulties confronting the professional specialist, one of the most serious is the problem of being aware of, and able to utilize, the results of research and up-to-date thinking in fields other than his own. There are, however, encouraging signs that this difficulty is being recognized, and that something is being done about it. Recently, the use of "interdisciplinary" research teams has led to fruitful results, especially where a problem has complex roots in several areas. For example, a study of the causes of juvenile delinquency in a particular city might involve an interdisciplinary team consisting of a psychiatrist, and economist, a city-planning expert, and a sociologist. Another encouraging sign is the increasing use of modern computing techniques to facilitate the processing of data for research in the social sciences as well as in the physical sciences.

A third area of encouragement involving the exchange of professional information is the growing emphasis on the "teaching" part of "engineering teaching," because this involves a need to know what the research and experience of the professional specialists in education have revealed about the ways in which people most effectively learn. It is the purpose of this article to reach into the great wealth of this information and to attempt to state, as briefly as possible, a few of the findings that may have implications for engineering teaching. The points listed have emerged from the tremendous number of research studies of the various aspects of the learning process, carried on during the last twenty years. In curriculum theory as well as in educational psychology, research is the cornerstone of all the modern work being carried on. Indeed, the healthy skepticism of the physical scientist for unverified ideas has long since been put to use by the educator, and the result has been a rather complete reversal of many of the older theories.

Let us then list, and briefly discuss, a few of the results of the research in education, which have implications for engineering teaching.

1. *The efficiency of learning has been found to be closely related to the meaningfulness of the material presented, in terms of the student's interests and purposes.* The research indicates that the stronger the student's motivation, the more efficient will be the learning process. The important thing to note here, however, is that the determining factor is the student; *his* interests and purposes and motivations are the factors—not the motivations that he should have, or may have

later, or that the faculty suppose him to have, or expect of him. Thus we must deal with the student as he comes to class, in terms of his actual interests and purposes, at that given time. It is obvious that this is extremely difficult, in a situation which involves a whole classroom; yet this is an important principle of learning. One significant corollary of this principle is that it thus becomes important to find out "where the student is now" in terms of both his informational background, and his motivations. Another corollary is that although all members of a given group may have approximately the same informational background, the motivations may be vastly different, and thus the "spread" of learning efficiency may be correspondingly great.

This does not, in any sense, mean that a student's interests and motivations cannot be changed. Indeed, we should expect that they will change, as the student is led by the faculty to see the profession, and his part in it, more and more clearly. Thus, at any given stage in his academic career, the student's "readiness" for effectively learning a given type of material will depend on his present interests and purposes, which will in turn be conditioned by his past learning experiences and by the way he views the future.

2. *The "internal logic" of a subject-matter field has frequently been found to be meaningless if the material is not already within the experience of the student.* To the engineering teacher, with his mastery of the concepts and abstract ideas of his field of specialization, the "internal logic" of a subject may have great appeal. Starting with the introduction of basic concepts and the development of fundamental principles, he can derive the whole superstructure, including the special cases, and the eventual simplified design equations. It all forms a logical pattern, and appeals to his sense of order. In advanced work, there is a very real need for this type of structuring of any field of knowledge. But the plain fact is that when a student is being introduced, for the first time, to a new set of concepts and ideas, his understanding grows best from a series of experiences, the more specific the better. Very often a beautiful logical structure is meaningless to him because he cannot understand "what it is all about." This series of introductory experiences may not lend itself to any logical pattern, yet from the *student's* point of view it yields him a foothold which the "logical order" method may deny him. In the initial formation of sound and correct concepts, it has been found effective to bring the student into contact with the material at several different times, from different viewpoints, and at different levels of difficulty.

3. *Learning has been found to be most effective if generalizations and abstract ideas are based on the student's experiences with specific and concrete materials, and if the student makes his own organization from his own experiences for purposes that are meaningful to him and suited to his own maturity.* This summary statement embodies the two points already mentioned, and adds a third, namely that it is valuable to "set the stage," so that the student can make his own relational structure, at his own level of the material he is learning. The evidence from the research indicates that it is the process of going from the understood to the new, from the specific to the general, and from the concrete to the abstract, which allows the student constantly to reorganize his thinking at succeedingly advanced levels of sophistication. In this way, difficult abstract concepts are soundly built up, and eventually the student is ready to attempt an organization of the whole field, and to appreciate its internal logic, because now its components and relationships have meaning for him.

4. *Learning is an actual activity.* For a long time, learning was thought of as a kind of absorbtion process. Gradually, as ways of teaching other than the lecture method were tried, and as the body of research information in both psychology and education grew, it became apparent that the word "activity" conveys a much

truer picture of what the learning process actually is. In the light of the research, learning is now conceived as modification of behavior, whether this behavior is a method of skiing, or a method of attacking a problem, or an active set of attitudes. In order for this modification of behavior to occur, the learner must interact with his environment, whether this environment be a complex of ideas or a playing field. In other words, the learner is active. Educational activities which require the learner to participate actively are therefore valuable, and this is the basis, in educational theory, of the so-called "project method." Engineering education, with its laboratories, field trips, research studies, and construction projects, is particularly well equipped with opportunities for active student participation. Seminars, group investigations, and individual study are also valuable ways to encourage "active" learning. Even the lecture method, inherently fraught with the ever-present possibility of an entirely passive audience simply copying the blackboard, can, if properly handled, trigger a tremendous amount of aggressive mental action in the classroom.

5. *Learning has been found to be more effective if students feel they have a share in planning the goals and the process.* Quite apart from the impressive amount of evidence on this point, there are other interesting aspects to consider. The value of activity in learning has been mentioned earlier. Here the opportunity is to utilize activity, not only to enhance learning of subject matter, but also to focus student attention on goals and on the learning process itself! Also, from the standpoint of the evidence about the need to "start where students are," allowing students to share in the planning of a course can be a highly useful method of assessing present status. Still further, we may note the value of developing, in the students, the feeling that material and method is, at least partially, their own responsibility, and geared to their own goals and backgrounds.

6. *Attitudes and emotions brought by a student to a learning situation have been found to affect greatly the student's ability to learn.* In several ways, engineering is in a particularly favorable position in this regard, since most of the students studying in this field are doing so because they want to. The glamor and obvious immediate applicability of the physical sciences in general, and of engineering in particular, predispose the student in a way very conducive to maximum learning. Also, there is very little chance for previously acquired emotional bias to affect learning, as is frequently a problem in areas such as philosophy, sociology, or aesthetics. Engineering courses are generally not required if the student is specializing in another field, whereas the reverse is not as true. This means that with a few exceptions, engineering courses are not attended with the attitude implied by the expression, "I have to get this over with." In some engineering courses, however, this is the very attitude found, particularly where the material is of a non-technical nature, as in courses in report writing, public speaking, and other aspects of professional life. Recognizing the value of a positive, constructive attitude in facilitating learning, many instructors in such courses spend a reasonably large block of time at the beginning of the term, developing in the students' minds this mental readiness, of which we spoke earlier. This can be done by showing, in various ways, that the material does have a practical value to the student. Obviously, too, the attitude of a student toward his instructor is a powerful force in a learning situation.

7. *Learning does not take place in isolation.* Contrary to many earlier ideas, the evidence from the research has now shown that learning is affected simultaneously by the whole complex of forces and situations, within and surrounding a human being, no matter where he is, He interacts with his environment, and thus learns, as a whole person, not simply as an "intellect." Attitudes, desires, and capacities are factors that are all molded

by, and themselves mold, the opportunities, pressures, and the people involved in the total learning situation. Thus, many complex adjustments take place at once, and the "total effective curriculum" is a sort of vector sum of all the experiences with which a student comes in contact. The individual and his personality may be thought of as forces in a larger field of force, which is his total environment. Any change anywhere will cause a readjustment of the whole field. Indeed, this is the so-called "field theory" of learning, which is gaining ever wider acceptance among educators as a clear picture of the learning process. In this light, consider such things as the student's attitude toward his future, a feeling of pressure from a high work load, or regular contact with an inspiring faculty member. If we are to be realistic about the effectiveness of our educational process, we cannot afford to treat these matters lightly.

An Engineering Curriculum Designed for Today's Student

By B. LEIGHTON WELLMAN

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The engineering curricula of today—and yesterday—are "on the block." They are being assailed from many directions by innumerable engineers and educators who believe that the conventional and time-honored program of engineering education is becoming increasingly inadequate for modern needs. The report of Dean S. C. Hollister and his committee on "Adequacy and Standards of Engineering Education"[1] has fanned the smouldering fire of dissatisfaction, and it is probable that many faculty committees have been impelled to reexamine their own programs. But while committees are meeting and debating, papers are being written, conferences are being held, and the air around every small gathering of professors is blue with smoke and argument. In all this talk one common fact is evident: there are as many opinions as there are individuals who hold them. Thus it is with some temerity that this writer proposes to discuss his own personal opinions, and to advance a few bold suggestions for the improvement of present day engineering curricula.

Considered from a purely pragmatic viewpoint, an engineering curriculum should be a carefully designed educational process whereby certain specially selected but undeveloped raw materials are processed and converted into an end product having known and desirable characteristics. It is also axiomatic that any continuously successful process must be adjustable to variations in the incoming raw materials, and it must also be improved and modified according to the need and demand for the outgoing product. It is entirely logical, therefore, that the specific and detailed design of a curriculum should be based upon an accurate and realistic evaluation of the high school graduate of today and the engineering graduate of tomorrow.

Different Background

The high school graduate of today is very different from his predecessors. His education has been designed for living, and the question of whether or not this has resulted in better citizens need not be debated here. For the student who wants to become an engineer, the change has been detrimental. Since the number of hours spent in the classroom and on homework has remained the same or been diminished, the addition of more interesting subject matter has obviously reduced the time devoted to the three R's. Basic concepts are still being taught, of course, but the long hours of drill that make for mastery are no longer available. Unfortunately the effect is most pronounced in simple arithmetic and algebra. Witness the college freshman who can solve a quadratic equation (with the proper formula), but fumbles pitifully when asked to mentally multiply ⅞ times ⅔. To stem this tide in the elementary schools is probably hopeless; in the secondary schools the intervention and cooperation of college educators may bring about

[1] "Report of Committee on Adequacy and Standards of Engineering Education," *Journal of Engineering Education*, January, 1952.

some improvement; but the engineering colleges must realistically recognize today's level of achievement in mathematics, and design their curricula accordingly.

The home life and social environment of today's high school student has also changed rapidly and radically from that enjoyed by Dad. Sports demand more and more time: they must be practiced for hours, participated in, cheered from the bleachers, and now watched on television. Clubs and organizations spring into being on the slightest stimulus to be nurtured by more hours of attention. For the student who would like to study, the number and variety of available distractions is almost overwhelming. All of these things consume the waking hours, and regardless of how we may value them, they do precondition the college freshman.

Time Element

For most of the above activities the average high school student has adequate time because he is carrying a schedule of only four, or at the most five, subjects' and his homework requires only an hour or two per day. But even the hardiest and most determined young man is stunned by the initial impact of his college engineering program. This new schedule upon which he has suddenly embarked will have five, six or even seven major and difficult courses. To this may be added orientation lectures, compulsory physical education, and probably several hours per week of military training. The number of intensive classroom and laboratory hours will total at least 30, and may be as high as 35. Certainly his days are full and there is little time for dawdling, but his evenings and weekends are also carefully planned. He quickly learns to expect 4 to 6 hours of preparation each day, and the weekends become only a means of completing assignments that couldn't possibly be done during the week.

That the above description of a typical engineering program is not exaggerated can be verified by examining the catalogs of the various colleges of engineering. Credit hours per semester will range from 17 to 19, with the majority inclining toward the higher figure. Since it is a common practice to consider three hours of work—classroom, laboratory and preparation—the equivalent of one credit hour, it is apparent that the work week will range from 51 to 57 hours. And this is for the average student and assignments that are not unduly ambitious! Of course it must be admitted that this heavy program has been completed successfully by thousands of young men, but the fact remains that today the transition from high school to college is abrupt and difficult for many students.

The general knowledge possessed by today's high school student concerning the world around him is amazingly extensive and diverse. By close association he has somehow acquired a smattering of knowledge about radio and television, about bicycles and automobiles, about airplanes and jet engines. But in spite of this interest in engineered products his acquaintance with simple hand tools and elementary manufacturing processes is extremely limited. Small apartments, basementless houses, and increasing urbanization are producing a new generation of manually inept and mechanically ignorant freshmen. And a surprisingly large number of these unskilled and inexperienced young men enter our engineering colleges, bringing with them only a desire and a probable aptitude for the career they have chosen. Certainly an engineering curriculum ought to be designed to correct in some measure this modern deficiency.

They Want To Be Engineers

But the great majority of students who enter engineering do have one thing in common: they want to be engineers, and they are normally enthusiastic about the prospect; they excitedly anticipate a prompt introduction into the intricacies of whirring gears, ingenious machines, river spanning bridges, towering structures, complex chemical plants, and all

of the many magical accomplishments of engineers. The bright-eyed eagerness of September warms and stimulates the vacation-refreshed professors. Months pass, interest wanes, and in the cold gray light of December it is sadly evident that there will be no engineering this year. English, History, Language, Chemistry, Physics, Mathematics, Drawing—this is the diet, almost entirely devoid of flavor or seasoning, that must be gulped down during the first year. There may be a soporific hour per week of well diluted engineering orientation, and the drawing course may touch upon a few glimmering mechanical terms, but in general the meat course will not be served until later. Motivation is much discussed, but most engineering colleges have yet to recognize its psychological importance by peppering the dish to make it tasty.

We might summarize, at least in part, the properties and characteristics of our raw material as: 1) a weakness in arithmetical skill, 2) inexperience in concentrated study, 3) a lively interest in nonacademic fields, 4) a lack of simple practical experience, and 5) a strong initial desire to participate in engineering experiences. These are generalizations, of course, but they are sufficiently characteristic to warrant sober consideration, not only in the design of the curricula, but also in the planning of extra-curricular activities and student counseling.

End Product

Turning now to the end product—the result of four years of intensive instruction and stern tutelage—let us consider what its properties are, or ought to be. The engineering graduate will, of course, almost inevitably, have acquired a fund of facts—more or less related and of some utility. But his real strength will lie in his sound knowledge of basic principles, and his keen appreciation of their possible applications. His knowledge of actual engineering practice will be meager, but his future employer has special methods and techniques, and will therefore expect, and frequently insist, that he alone can give proper instruction here. Hence his employer will naturally expect a thorough knowledge of fundamental principles and little of special topics. This situation is commonly acknowledged, and lip service given thereto, yet at the same time more and more advanced and specialized subjects are piled on top of the inverted educational pyramid. Since the time dimensions of the pyramid are limited, even strained, the downward pressure of the advanced material is squeezing out the introductory subjects. Thus the elementary and fundamental topics are being shortened, abridged, and even eliminated. Such a course of action must eventually weaken the product. Advanced topics must, of course, be available to those who want and can use them, but not at the expense of basic kowledge.

It has been rather aptly said that the engineer is a man who deals with the four M's—men, money, materials and machines. Of materials and machines our engineering graduate has learned a great deal. Of men and money he is apt to be colossally ignorant at the time of graduation. It is his salvation that in the years ahead he will rub shoulders and temper with many men, and thereby learn in the hard school of experience how to live and work with them. But this live and learn process could be greatly expedited by a few brief studies in psychology, management, and labor relations.

Of money little or nothing is said during the usual engineering course. The physical attributes of materials and machines are meticulously studied, but rarely are the actual and relative costs mentioned. Labor, materials, and engineering are key elements in the cost of a product, and their comparative importance is frequently ignored or dismissed as of little interest. Yet students are usually keenly and realistically interested in the cost of a milling machine, a die, or a ball bearing. Cost accounting, purchasing, marketing, and allied subjects might very well deserve a small place in the modern engineering curriculum.

Outside of his workaday world the en-

gineering graduate should be prepared to assume a responsible place in the social, cultural, and political work of his community. That he has not done so in the past has been attributed to his narrow and highly specialized education. To correct this deficiency many engineering colleges have in recent years added a "band of cultural subjects" to their already overcrowded curricula, but not of course without some reduction in technical subject matter. The width of the "band" varies, but the arbitrary figure of 20 per cent that has been advocated by proponents has been adopted by a number of colleges; other schools have found it necessary or desirable to limit this aspect of their culture to a lesser amount. No attempt will be made here to list the many courses that are customarily included in this category, nor to debate their place in that list.

Unresolved Points

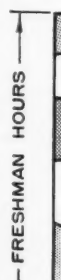
Sincere and well intended as these efforts toward cultural improvement may be, several points remain unresolved in the opinion of this writer. Has the introduction of these courses actually accomplished the desired end? Or is the engineer by nature and inclination exclusively interested only in his own field, and therefore immune to the innoculation? Unfortunately, statistical evidence is lacking. How can we accurately establish the necessary allocation of time to this study, and at what point will the soundness of the technical instruction be imperiled? Here again the writer knows of no unbiased factual information on this subject, and it may be that such data can never be accurately formulated. Perhaps the intangible values ascribed to these courses must continue to be accepted on faith, but the pressure for more and better technical instruction within the confines of four years' time demands a more critical attitude. The general cultural course that crowds or displaces a technical subject should certainly be one of unquestionable value to today's graduate engineer. Any other—however venerable and hoary—should be suspect.

It should be understood that the writer is by no means antagonistic to the inclusion of nonengineering subjects in the engineering curriculum, but rather feels that these courses should be selected with the greatest care. They will necessarily be introductory in nature and designed primarily to implant the seed of intellectual curiosity. Though most of the seed will fall on barren soil, some will germinate and flourish for many years under the cultivation of a natural interest. Immature freshmen having a pronounced scientific bent are notably unreceptive to such subjects, but mature juniors and seniors are inclined to be more appreciative of their potential value, hence it would be desirable to put the nontechnical courses into these later years.

Desirable Characteristics

In summary, our end product should possess the following desirable characteristics: 1) a sound fundamental knowledge of engineering facts and principles, 2) a limited introductory knowledge of advanced topics, 3) some knowledge of human relations, 4) an appreciation of monetary values in engineering, 5) a breadth of interest that will enable him to fit usefully and harmoniously into the life of his community. Achievement of these objectives should be the goal of our engineering colleges.

If it is agreed that the foregoing objectives are desirable, and if it is conceded that today's high school graduate has been described with reasonable accuracy, then these initial and final conditions ought to serve as a guide in the design of an engineering curriculum. And the term "design" is used here with all the implications of original creative effort. Many curricula are revised, but few have been designed. Revising a curriculum is customarily and traditionally a process of shifting small discrete packets of knowledge, known as courses, from one hour, semester, year, department, or pigeonhole, to another. The size of the



packets may be altered, but the contents are rigidly prescribed and rarely allowed to mix with, or be contaminated by, the contents of closely related packets. Of course the dimensions of the packets are dictated by the clock, but if all the contents were dumped into a common vessel, stirred with an enlightened spoon, and mixed with understanding and tolerance, it is entirely possible that the mixture could be strained, sorted, and recombined into new packets. And it is conceivable that these new units might form a better and more logical sequence of instruction than did the original assortment. Certainly much of the repetitious, overlapping, and extraneous material could be eliminated, but this integration and streamlining could be achieved only by an almost complete disregard for traditional departmental domains. And these ivy-clad walls would be the greatest obstacle of all.

Logical Parts

If we boldly proceed, however, to spread before us the total contents of all the packets of knowledge, it would soon be apparent that the whole can be divided into three logical parts:

1) The languages of engineering, of which there are three: mathematical, graphical, and verbal. These three modes of expression are employed continually by the engineer, and he must become fluent in their use at an early stage of his studies. They might also be called the "tool courses" of engineering.

2) The general field of engineering, in which there are three broad divisions: materials and processes, energy, and personnel. Knowledge and understanding in these three fields must logically be followed by use and application in order that the separate principles of each may be integrated and directed into two channels: design or synthesis, and testing or analysis.

3) The studies in living, of which there are many. These are the studies that lead toward a broader viewpoint and a more tolerant understanding of the non-engineering world in which the engineer must live. They are—to some degree—essential to his social and personal development.

Within each of the above broad classifications of knowledge, logical sequence and desired achievement should be of paramount importance. The stream of

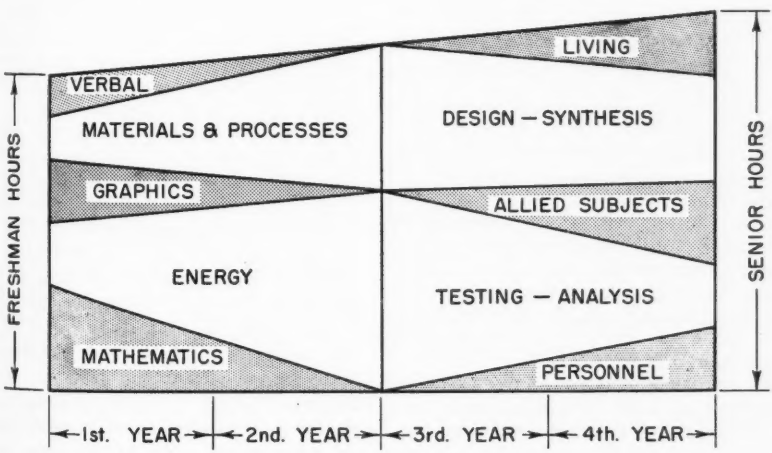


FIG. 1. The tapered engineering curriculum in conventionalized form.

learning should flow smoothly and continuously forward even though the pace must be adjusted to that of parallel and concurrent studies. For administrative and calendar reasons the flow will be regularly interrupted, but the division of knowledge into individual courses should not be unduly influenced or prejudiced by presently existing courses, staff idiosyncracies, or departmental organizations. Neither should the divisions of knowledge be so small as to scatter attention or break the unity of learning. Five subjects at any one time would be a desirable maximum.

Without attempting to further subdivide the above fields of learning, let us fit these major units into the standard four-year program. The chart shown in Fig. 1 is a conventionalized representation of the proposed course of study. The height of the chart is proportional (ideally) to credit hours per semester (or hours of study per week). It tapers from a relatively light program at the beginning of the freshman year to a somewhat heavier schedule during the senior year. This feature is obviously designed to ease the transition from high school to college. The heavier schedules of the junior and senior years can easily be carried by these mature and more experienced students.

Languages of Engineering

During the first two years the languages of engineering—verbal, graphical, and mathematical—begin heavy and taper to completion as shown by the shaded triangular areas. At the same time the engineering courses—divided into only two broad classifications—begin light and gradually increase in time allotment. These five areas represent five course sequences, and the relative heights of the areas represent the approximate allotment of time to each field. (Physical education and military training have been omitted from the chart but must be considered in the total time allotment.) Because of its vital importance, and for reasons previously discussed, mathematics has been given the largest initial share of time. Graphics is second because the entering freshman has had little or no previous instruction in this field. Verbal is third because it has received considerable attention in high school.

Materials and processes should begin in the shop with the forming and fabrication of common materials. This is not only a simple and elementary starting point, but it is also an opportunity to acquaint the novice with the basic tools of engineering and to fill certain voids in his vocabulary. The chemistry and metallurgy of materials would follow.

Energy in its various forms—mechanical, thermal, electrical, atomic—should also be studied in orderly sequence, and that order would not necessarily be that of classical physics, nor would all topics necessarily be taught by physicists. Theory and engineering applications would be taught in unison in engineering laboratories with engineering equipment by engineers.

During the last two years the engineering courses gradually lighten to allow increased time for allied subjects, living, and personnel courses. At the beginning of this last two-year period the student will have acquired a sufficient basic knowledge of materials and energy to embark upon the more creative work of design and analysis. Here he must draw upon his entire fund of knowledge, employ all of his tools, and combine ideas from various sources to solve his problems. This is the synthesis of all that has gone before. Here too will be the testing of larger and more complex equipment, the analysis of performance where different sciences and principles are involved.

The allied subjects include those fields of engineering that lie slightly outside the chosen major field of study but are so closely akin to it that they must necessarily be included in the program. The studies in living and personnel are included in this later period in order that the more mature students may better appreciate their values.

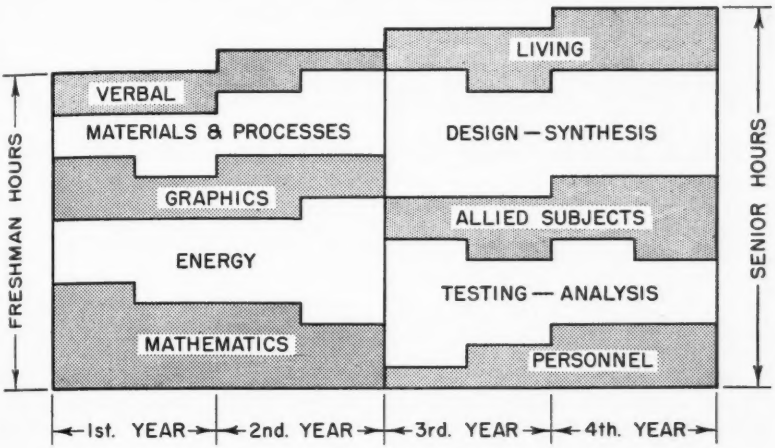


FIG. 2. The tapered curriculum as it might appear in standard credit hour form.

Fig. 2 shows the general pattern of Fig. 1 as it might appear after being adapted to standard credit hour form. Here the ideal triangles and trapezoids have been changed to the rectangular blocks necessitated by traditional educational procedure, but the general trends of Fig. 1 are still apparent. It should be understood, of course, that the particular pattern shown in Fig. 2 is purely illustrative of a broad concept: no special significance should be attached to the relative heights of the blocks. The fact that consecutive blocks do not increase or diminish in perfect order is an intentional distortion introduced here to show the inevitable effect of practical pedagogy.

Broad Pattern

Here then, in broad sweeping strokes, is a pattern for future engineering curricula. Its merits are probably debatable, and its method controversial, but it is to the best of the writer's knowledge original. To adapt it to an existing engineering college would be a laborious undertaking, and one fraught with many dangers and dislocations. It is probable that present tool courses could easily be adapted to this new pattern; the studies for living could be culled from a very wide field of learning without serious dissension; courses in personnel are young and flexible, hence very adaptable. But the division of engineering courses into two broad streams of logically integrated learning could only be achieved by a complete reexamination and reevaluation of the sum total of undergraduate engineering studies. The task is by no means impossible, but it would require the coordinated efforts of a group of learned and determined scholars. And the fruit of their labors might be sweet and nourishing to future generations of engineers.

Writing as Communication: The Engineer Must Learn How to Reach His Constituents

By JOHN I. MATTILL

Director of Publications, Massachusetts Institute of Technology

My own professional interest is in writing on technical subjects for audiences with limited technical background —sometimes none at all. This suggests that you are going to hear principally an account of the wonders of popularization —the work of Rudolf Flesh, and the other ways of making unpalatable material more useful to semi-technical and popular audiences. Before I reach this stage, however, there is a more fundamental subject of journalism to be considered; for I am deeply concerned with the broad relations of science and engineering to popular writing.

Journalism about scientific events has traditionally dealt with *facts*. Atomic fission has been described in popular language so many times since 1945 that it must now be as near to "common knowledge" as any scientific subject of moderate complexity. The electrons crossing between cathode and plate of a vacuum tube have been exposed to countless comparisons with more graphic phenomena. Members of the National Association of Science Writers have been writing good accounts of the accomplishments of science and engineering—such as these—for many years.

Yet those of us in public relations for science or technology discover, nearly every day, that something is missing. We have communicated *facts*—but we may have failed to communicate *meaning*. We have reached the ultimate point where we have to say, "I'm sorry but that comes out of the theory of relativity, and it's very difficult, if not impossible, to explain without quite a bit of physics and mathematics. You'll have to take it on faith." [1] But through all this we do not seem to have conveyed an understandable concept of what a scientist or engineer is really trying to do, what he can and cannot do, what are his purposes, how does he go about his stated work, . . . indeed, what science and engineering really mean.

You will all remember how the spring's concentration of tornadoes inspired calls for Congressional investigations of the Atomic Energy Commission—in the face of the most serious and careful deliberations and denials from all manner of scientists. I am worried that the demands were made; and I am worried that they could be taken so seriously, on so many sides, for this reflects a basic misconception of what scientists can learn with what degree of certainty. It is a demonstration of the common difficulties in understanding what the scientist and engineer is about.

Major Misconception

The tendency in journalism seems to be to set scientists apart as experts—like statues towering above and uncomprehending of other mortals. But this is a major misconception: a scientist is not, after all, any more elevated than his fellow men. Are not scientists and engineers very much like the rest of us, so far as their approach to their problems is concerned? "The stumbling way in which even the best of the scientists in every generation have had to fight through thickets of erroneous observations, misleading gen-

eralizations, inadequate formulations, and unconscious prejudice is largely neglected by those expounders of the alleged scientific method who are fascinated by the logical rather than the psychological aspects of experimental investigations," says Dr. James B. Conant in his useful volume on "Science and Common Sense." [2]

It is hard, too, for those steeped in the tradition of scientists as experts to understand that these men admit and comfortably live with an inability to resolve some of the basic facts of the physical world . . . the wave vs. the corpuscular theories of light, for instance. The scientist's answer to a question on this matter is simply that the question has no meaning: "We physicists have stopped asking it; but if you insist, we may say that a beam of light is at one and the same time a set of particles and waves. If the solidity of matter seems to have gone out from under you, don't for a moment think that this has impeded the advance of science, for quite the contrary is the case," as Dr. Conant expressed it in recent lectures at Columbia University.[3]

The dependence of scientists and engineers on communication among themselves is another of the factors not commonly understood by nonscientists. But it must be a basic consideration in national policy bearing on the classification of scientific work and the international exchange of information and of scientists themselves. Only when you understand what science is and how it operates can you see what is meant by the familiar comment that no scientific fact can long remain a secret from another scientist. Only when you know something about what Dr. Conant has chosen to call "the tactics and strategy of science" can you see why the so-called McCarran Act is subject to such widespread criticism from scientific and professional people.

These are some of the things about science which need to be better known throughout this country, by people in non-scientific activities and especially by people who administer work which depends on scientists or engineers. This includes the vast majority of our voting citizens, the "new lay administrators of science," they have been called.

As I see it, this problem relates very especially to teaching engineering and science students how to write and to be in general articulate. These are things about science and engineering which your students may need to put across to their supervisors in years to come. They are things which all scientists and engineers must carry to their "constituents" everywhere. This seems to me of paramount importance to students of science and engineering because they will be in the small minority of our citizens who have behind them the experience of work in science or engineering. Laymen, Dr. Conant says, fail to understand "the tactics and strategy of science" because of a fundamental ignorance of what science can or cannot accomplish; only those who have personal experience in the profession seem able to overcome this hazard; theirs is a special point of view which comes only from work in science or engineering.

Communicating Ideas

If the future of science depends on how widely scientific activity is understood—and this may indeed be the case—then the future of science may well depend on how literate is our coming generation of scientists and engineers—on how well they can tell this story to those whom they meet. Telling it is not an easy task at best, and my frequent references to Dr. Conant's writings are intended to be most complimentary. He has written and talked about these things in an extraordinarily effective way—in lectures at Yale University, published as "On Understanding Science" [4] later expanded to "Science and Common Sense," and at Columbia University, published as "Modern Science and Modern Man."

Already my approach to this matter of writing has been that of a journalist: I am concerned more about communication than grammar; I put the utilitarian aspects of our language ahead of the

academic. This is to say, I do not consider writing to be principally a problem of grammar and syntax, vocabulary as such, and precise expression. I try not to spend most of my effort on the frills and decorations: a split infinitive holds no terrors, and punctuation can be put in or left out on the basis of its need for adequate comprehension. I consider writing as a problem of effectively communicating ideas.

This approach begins with an analysis of the audience for which the writing is intended—its requirements as to subject matter, interpretation, and readability. Words must be tailored to the audience which will read them—be that audience the technical director, the project financial officer, the company executive, the industrial specialist, the scientist in an unrelated area of interest, the nonscientist with a clear interest in the subject, or the nonscientist who has no apparent reason to care.

Tailoring writing to its audience is not so easy as it may sound. The audience, in general, knows less about the subject than you or I anticipate—and, almost without exception, needs more interpretive information than most of us would normally choose to provide. This business of tailoring writing to its audience is the principal point of the applied psychology developed by Dr. Rudolf Flesch of Columbia University. His books—"The Art of Plain Talk" or the later "The Art of Readable Writing"[4a]—are the best demonstrations I know of the practical value of what he has to say. These books are often used as textbooks of writing; they need to be supplemented principally by some good thinking on the nature and methods of interpretation in writing.

Journalists' Approach

The journalists' approach to learning how to write is to *write*—just as some learn to swim by being tossed off a pier into deep water. The analogy can perhaps be carried further: after that first start, swimming strength is built up by watching and copying others and by swimming more and more in the process . . . not by listening to and practicing stylized techniques. The result may not be suitable for the Olympics—few journalists claim that their works are literary masterpieces—but it surely prevents drownings.

When this approach is applied to teaching writing, you are sure to end up with someone who can write *something*—who is not completely tied in knots by the appearance before him of an assignment and a typewriter.

What he is asked to write about is also important. Journalism by definition is writing about real events; journalism schools keep away from assignments which involve their students in theoretical or imagined situations.

In the engineering environment, some writing can clearly be a part of the requirements of other courses, taking the form of laboratory reports and assigned papers. But most of it should be for even larger ends—for actual publication and so for actual service in the business of communicating ideas. This can mean publication in the college newspaper, or in the school's magazine. But, most important I think, it can mean contributing to technical and professional journals of national scope.

There are several hundred such journals.[5] Many of their editors are anxious to have good technical reporting about the research activities in colleges and universities—and, to a lesser extent, about the educational developments as well.

Let engineering English students turn themselves into reporters; with your help as editor, they can be sure of turning out something—and before long, too—which can end up in print with a by-line and often a small check to make the ultimate reward a financial as well as a professional one.

My enthusiasm for this proposal is based on personal experience. I can testify to the inspiration which comes to

a student who deals directly with the editor of a publication which he sees and respects—who perhaps becomes that editor's unofficial correspondent for the college in which he studies. This motivation is worth a great deal. It combines the experience and training in writing with the professional advancement and orientation which comes to an author. I think it can help us turn out literate engineers who find writing a pleasant and perhaps even easy experience.

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4. Conant, "On Understanding Science," Yale University Press, 1947.

4a. Harper and Brothers, 1946 and 1949, respectively.

5. See "Directory of Newspapers and Periodicals," N. W. Ayer & Son, Inc.

College Notes

The **University of Michigan**, College of Engineering, has announced two Intensive Courses in Automatic Control. The first is scheduled for June 14 to 19 inclusive, and the second for June 21 to 23, 1954, inclusive. The courses are built around the principles and application of measurement, communication and control. Course I will consist of the fundamentals in each of these fields and will include some fundamental work in nonlinear systems. Course II will take up applications of the fundamentals to more advanced problems.

April 15 is the closing date for registration. Further information may be obtained by writing to Professor M. H. Nichols, room 1523, East Engineering Building, University of Michigan, Ann Arbor, Michigan.

ASEE Summer Institutes—1954

Science and technology are moving rapidly ahead in broad areas which hold significant promise for the future of engineering. In order to assure maximum progress in engineering education and to expedite the translation of new fundamental concepts into engineering practice, the American Society for Engineering Education is inaugurating this year a series of conferences to be known as Summer Institutes. This program will help to implement the recommendation of the ASEE Committee on Engineering Education that modern physics, including nuclear science and solid state physics, should become an essential study in engineering education.

Each Summer Institute will deal with a specific subject matter area. The purpose of the Summer Institute is to seek out and clarify fundamental concepts, to assess the material as to its importance in engineering education, and to arrive at a logical orderly pattern for teaching purposes. By this positive approach, it is hoped to bring engineering education into closer proximity to the significant new developments which will affect its future. In these conferences, the divergent viewpoints of the research engineer, the scientist, and the educator will be brought to bear upon the problems.

Two Summer Institutes are planned for 1954—one in Sold State Physics in Engineering Education and the other in Nuclear Physics in Engineering Education. Both conferences will be financed by grants from the National Science Foundation. Each Summer Institute will consist of a working conference of 20 to 30 leading authorities in the particular field who will make a comprehensive analysis of the material and lay the groundwork for the open conference. The open conference will feature about 6 to 8 of the participants of the working conference, discussing important fundamental concepts and organization of the subject matter as it relates to engineering and engineering education. There will be ample opportunity for open discussion by those in attendance.

These conferences are supported in part by grants from the National Science Foundation. The American Institute of Physics is cooperating in the Nuclear Science Foundation.

Solid State Physics in Engineering Education

University of Illinois—March 8–10, 1954

This will be a working meeting of leading physicists and engineers specializing in this field. Attendance by invitation only.

Carnegie Institute of Technology—June 21–25, 1954

Open to engineering and physics teachers. Attendance will be limited to 150. For information and registration forms write to Professor John W. Graham, Carnegie Institute of Technology, Pittsburgh, Pa.

Nuclear Science in Engineering Education

Columbia University—April 22–24, 1954

This will be a working meeting of leading physicists and engineers specializing in this field. Attendance by invitation only.

Northwestern University—September 7–11, 1954

Open to ASEE members. Attendance will be limited to 100. For information and registration forms write to Professor Robert L. Young, Technological Institute, Northwestern University, Evanston, Ill.

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ASEE Summer Schools—1954

The following Summer Schools, sponsored by ASEE Divisions, are open to ASEE members. For information and procedures as to registration, please write to the person indicated in connection with the particular Summer School. All of the Summer Schools at the University of Illinois either precede or follow the Annual Meeting so that those in attendance can combine Summer School attendance with attendance at the Annual Meeting. The program for the Annual Meeting of the ASEE will be mailed to Society members during the last week of April.

Economics of Engineering Summer School sponsored by the Engineering Economy Commitee.

Theme: "An Evaluation of Analytical Techniques of Engineering Economy."
Time: June 12–13, 1954. *Place:* University of Illinois, Urbana, Ill.
Information: Professor Arthur Lesser, Jr., Head, Industrial Engineering Dept., Stevens Institute of Technology, Hoboken, N. J.

Electrical Engineering Summer School sponsored by the Electrical Engineering Division.

Theme: "The Elements of Design of Digital Control Circuits."
Time: June 18–20, 1954. *Place:* University of Illinois, Urbana, Ill.
Information: Dr. L. V. Bewley, Dean of Engineering, Lehigh University, Bethlehem, Pa.

Summer School in Advanced Engineering, with Emphasis upon Development of Creative Thinking jointly sponsored by Educational Methods Division and General Electric Co. Attendance by invitation only.

Time: Aug. 30–Sept. 4, 1954. *Place:* Schenectady, N. Y.
Information: R. H. Buescher, Technical Education, General Electric Co., Schenectady, N. Y.

Workshop for Humanistic-Social Project sponsored by Humanistic-Social Division.

Time: June, 1954. *Place:* University of Illinois, Urbana, Ill.
Information: Professor Sterling Olmsted, English Dept., Rensselaer Polytechnic Institute, Troy, N. Y.

Engineering Mechanics Summer School sponsored by the Engineering Mechanics Division.

Theme: "Evaluation of the Engineering Significance of Graduate Training in Mechanics."
Time: June 11–12, 1954. *Place:* University of Illinois, Urbana, Ill.
Information: Professor Dan Pletta, Virginia Polytechnic Institute, Blacksburg, Va.

Summer School sponsored by the Mechanical Engineering Division.

Theme: "Teaching of Machine Design and Manufacturing Processes."
Time: June 18–25, 1954. *Place:* University of Illinois, Chicago, Ill.
Information: Professor K. E. Lofgren, Machine Design, Cooper Union, New York, N.Y.

Do You Know—

(*Continued from page 420*)

► For the Instrumentationalists, there will be a one-day conference on instrumentation on Saturday preceding the Annual Meeting at Urbana. Professor Bob Jeffries at Michigan State will gladly supply information.

► As the time draws nearer for the Annual Meeting and our Secretarial desks sag under the ever rising avalanche of mail in preparation for the Meeting, we can't help but feel grateful for the competent crew at the University of Illinois which has been working diligently all year planning the multitudinous details for the Meeting. They're doing a grand job and we want you to know it. Lisle Rose, our genial Chairman of the Local Committee, is now hale and hearty after his bout with the Surgeon (he lost) and is moving along at his usual jet propulsion pace.

See you at Urbana.

Best regards,
ARTHUR BRONWELL,
Secretary

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	University of Pittsburgh	April 30–May 1, 1954	W. I. Short, University of Pittsburgh
Illinois-Indiana	Illinois Institute of Technology	May 15, 1954	R. G. Owens, Illinois Institute of Technology
*Kansas-Nebraska	University of Nebraska	Fall, 1954	M. H. Barnard, University of Nebraska
Michigan	University of Michigan	May 8, 1954	F. L. Schwartz University of Michigan
Middle Atlantic	Lafayette College	May 8, 1954	H. M. Jenkins, Swarthmore College
Missouri-Arkansas	Missouri School of Mines	April 10, 1954	V. J. Blum, St. Louis University
National Capital Area	Catholic University	May 8, 1954	C. H. Walther, George Washington University
New England	Massachusets Institute of Technology	Oct. 9, 1954	E. R. McKee, University of Vermont
North Midwest	Michigan College of M. and T.	Oct. 8–9, 1954	C. J. Pratt, Michigan College of M. and T.
Ohio	Ohio State University	May 1, 1954	R. S. Paffenbarger, Ohio State University
Pacific Northwest	Oregon State College	April 23–24, 1954	L. Slegel, Oregon State College
Pacific Southwest	California Institute of Technology	Dec. 28–29, 1954	B. M. Green, Stanford University
Rocky Mountain	University of Utah	May 14–15, 1954	A. Diefendorf, University of Utah
Southeast	North Carolina State College	March 25–27, 1954	J. R. Cudworth, University of Alabama
Southwest	University of Texas	April 16–17, 1954	J. J. Heimerich, University of New Mexico
*Upper New York	Cornell University	October, 1954	N. A. Christensen, Cornell University

Members of the Society are welcome at all Section Meetings

* No Date Set.

New Members

ANDERSON, WALLACE, Professor and Head of Physics Department, The Citadel, Charleston, S. C. · C. T. Razer, John Anderson.

ANTOINE, TAMLIN C., Associate Professor of Technology, Hampton Institute, Hampton, Va. H. S. Shivar, L. K. Downing.

APPEL, DAVID, Instructor in Mechanics and Hydraulics, State University of Iowa, Iowa City, Iowa. C. J. Posey, F. M. Dawson.

AULD, ROBERT B., Industrial Coordinator, Assistant Professor of English, Fenn College, Cleveland, Ohio. M. B. Robinson.

AUSTIN, WILLIAM W., Associate Professor of Mechanical Engineering, N. C. State College, Raleigh, N. C. J. K. Whitfield, J. S. Doolittle.

BARCLAY, LELAND, Associate Professor of Civil Engineering, University of Texas, Austin, Texas. J. S. Doughtie, J. A. Focht.

BARKER, RICHARD C., Instructor in Electrical Engineering, Yale University, New Haven, Conn. A. G. Conrad, H. J. Reich.

BAUGH, ROBERT L., Assistant Professor of Electrical Engineering, Colorado School of Mines, Golden, Colo. H. E. Fletcher, A. L. Gosman.

BERKNER, LLOYD V., President of Associated Universities, Inc., New York, New York. E. A. Walker, E. B. Stanley.

BEYER, GERHARD H., Associate Professor of Chemical Engineering, Iowa State College, Ames, Iowa. D. R. Boylan, C. O. Frush.

BOGGESS, ROBERT L., Instructor in Electrical Engineering, University of Kentucky, Lexington, Ky. H. A. Romanowitz, C. T. Maney.

BOYD, LANDIS L., Associate Professor of Agricultural Engineering, Cornell University, Ithaca, N. Y. O. C. French, H. E. Gray.

BROWN, HOWARD E., Associate Professor of Mechanical Engineering, University of Texas, Austin, Texas. R. D. Slonneger, B. E. Short.

BROWN, OTTO G., Instructor in Mechanical Engineering, University of Texas, Austin 12, Texas. R. D. Slonneger, B. F. Treat.

BROWN, WARREN O., Dean of Men, University of Illinois, Chicago, Illinois. M. V. J. Dembski, S. E. Shapiro.

BRUSH, DON O., Instructor in Applied Mechanics, University of Illinois, Urbana, Ill. A. P. Boresi, W. E. Black.

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CHU, TING Y., Assistant Professor of Civil Engineering, Iowa State College, Ames, Iowa. L. O. Stewart, D. T. Davidson.

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COBB, CHARLES N., Associate Professor of Industrial Management, Alabama Polytechnic Institute, Auburn, Ala. W. H. Francis, L. M. Sahag.

CODER, CHARLES H., Jr., Assistant to Director, Academy of Aeronautics, New York, N. Y. W. M. Hartung, C. S. Jones.

COGAN, ISADORE, Assistant Professor of Electrical Engineering, Drexel Institute of Technology, Philadelphia, Penna. W. A. Holland, Martin Kaplan.

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GREEN, ROBERT L., Assistant Professor of Agricultural Engineering, Louisiana State University, Baton Rouge, La. L. J. Lassalle, L. V. McLean.

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Advertisements must be submitted not later than the first day of the month preceding the month of issue. Because of limited staff, the ASEE headquarters cannot maintain personnel files or supply detailed information about jobs. In replying to blind ads, address letters to American Society for Engineering Education, Northwestern University, Evanston, Illinois and give blind ad number. Information and rates for advertising in the Journal can be received by writing ASEE Headquarters. In order to conserve space and achieve uniformity, the privilege is reserved to rearrange advertisements.

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by J. Marin & J. A. Sauer

A revision of Marin's *Strength of Materials*, this text provides students of engineering with an introduction to mechanics of materials. With essentially the same organization, the text is completely revised to bring it up to date on the developments in important areas, including new chapters on experimental stress analysis and temperature and creep properties of materials. There is also new material on basic aspects of design, stress distribution and stress concentrations, stress on an oblique plane, vibration of beams, impact properties of materials, and fatigue.

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MODERN PHYSICS FOR THE ENGINEER

Edited by LOUIS N. RIDENOUR, Vice-president, International Telemeter Corporation, and Visiting Professor of Engineering, University of California, Los Angeles. In press

A collection of lectures delivered at the University of California at Los Angeles designed to provide the reader who has some technical knowledge with a brief account of some of the more interesting developments in the fundamental science underlying all engineering. Here is a significant contribution to scientific literature in the twentieth century.

MILLIMICROSECOND PULSE TECHNIQUES

By IAN A. D. LEWIS and FRANK H. WELLS, Atomic Energy Research Establishment, Harwell, England. *Electronics and Waves—A Series of Monographs.* In press

This is the fifth in a series published in cooperation with the Pergamon Press in England. The subject: the theory and design of electronic circuits and devices for operation in the range of time intervals which lie between the province of microsecond pulse circuits, as developed at the end of World War II, and the realm of microwave devices. Systems of large bandwidth are the primary concern of the book.

WAVE MOTION AND VIBRATION THEORY

Proceedings of the Fifth Symposium in Applied Mathematics of the American Mathematical Society. Edited by ALBERT E. HEINS, Carnegie Institute of Technology. In press

These papers were presented at the Applied Mathematics meeting held at Carnegie Institute of Technology in June 1952. The subject of the Symposium was *Wave Motion and Vibration Theory,* and the four sessions were devoted to *Stability of Fluid Motions, Hydrodynamic Waves, Diffraction and Scattering Problems,* and *Vibration Theory.*

COLLECTED PAPERS

By S. P. TIMOSHENKO, Stanford University. 642 pages, $15.00

This work contains practically all of Professor Timoshenko's published scientific papers, plus a short but fact-filled biographical sketch written by D. H. Young, student, colleague, co-author, and friend. The scientific works include Professor Timoshenko's writings in English, French, and German, as well as many of his early papers originally published in Russian and later translated or abstracted into one of the above languages.

FOUR PLACE TABLES OF TRANSCENDENTAL FUNCTIONS

By W. FLÜGGE, Stanford University. 136 pages, $5.00

Published in cooperation with the Pergamon Press in England, these tables are for use in calculations for which the order of accuracy afforded by the slide rule is sufficient. Containing formulas necessary to handle the functions, the tables deal with trigonometric, hyperbolic, exponential, and logarithmic functions, certain of the Bessel functions, and elliptic integrals, the Fresnel integrals, the error function, the sine-, cosine-, and exponential-integral functions, and the gamma function. Values in all tables are given to four digits, and except for the Fresnal integrals, are in error by no more than one unit in the fourth digit. The numerical tables are supplemented by definitions and lists of relevant formulas which serve, in particular, to permit the evaluation of each function for arguments outside the tabulated range.

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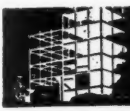

LIGHTNING PROTECTION FOR ELECTRIC SYSTEMS

By EDWARD BECK, Manager, Lightning Arrester Section, Switchgear Distribution Apparatus Engineering, Westinghouse Electric Corporation. *Westinghouse McGraw Hill Engineering Books for Industry.* In press

This practical guide to the protection against lightning of electric systems and equipment shows the nature of lightning and its effects, the various means of protection, . . . particularly for ac systems and apparatus . . . how to select and apply arresters, and what conditions to look for if trouble is to be avoided. Treatment is simple, using as little mathematics as possible and including many practical solutions and recommendations.

ACOUSTICS

By LEO L. BERANEK, Massachusetts Institute of Technology. *McGraw-Hill Electrical and Electronic Engineering Series.* In press

Recent advances in the field of modern acoustics are thoroughly covered in this important new text. Sections dealing with dynamical analogies, directivity patterns, acoustical circuits, loudspeaker enclosures, sound transmission through structures, noise reduction, speech communication and psycho-acoustic criteria make this the most up-to-date volume in the field. Those interested in any of the numerous phases of acoustics will find this a valuable addition to their libraries.

CONTROL SYSTEM DYNAMICS

By WALTER R. EVANS, Group Leader, Systems Group, Autocontrol Section, Electromechanical Engineering Department, North American Aviation, Inc., Downer, California. In press

An exposition of the "Root Locus Method" invented and developed by the author, this new volume demonstrates the techniques for determining the response of linear control systems. The root locus, a tool to factor an algebraic polynomial is useful in analyzing the pertinent differential equations in feedback control systems. Developing from the simple to the complex, each solution establishes a concept which permits a simpler technique to be applied to the next, more complicated, problem.

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Here is a thorough revision of a successful book for the use of servicemen and technicians. The author gives a practical description of television circuits, techniques and basic theory, and includes frequency mudulation. Using only simple arithmetic and algebra, the new edition includes expanded information on servicing, as well as a thorough chapter on color television.

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An up-to-date, well-organized treatment of the more important and useful methods of analog computation and simulation, with particular reference to engineering and scientific applications. The author carefully develops the theoretical basis for each approach, providing the reader with the tools necessary for applying these methods to actual problems.

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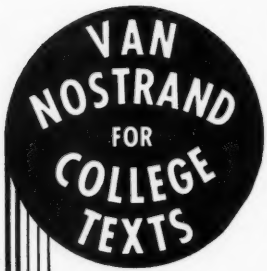

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